Monitoring and Management Plan

Kwinana, Western Australia

Prepared for:

Alcoa of Australia (Limited)

Prepared by:

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Acronyms

ADWG	Australian Drinking Water Guideline
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
AS	Australian Standard
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTOC	Below Top of Casing
CoC	Chain of Custody
CS Act	Contaminated Sites Act
CS Auditor	Contaminated Sites Auditor
CSR	Contaminated Sites Register
DO	Dissolved Oxygen
DSR	Detailed Summary of records
DEC	Department of Environment and Conservation
DGV	default guideline value
DTW	Depth to Water
DWER	Department of Water and Environmental Regulation
EC	Electrical Conductivity
EPA	Environmental Protection Agency
EPHC	Environmental Protection and Heritage Council
EQC	Environmental Quality Control
EQG	Environmental Quality Guideline
GME	groundwater monitoring event
HEPA	Heads of EPA
HPRO	high-pressure reverse osmosis
ID	Identification
KIA	Kwinana Industrial Area
LTV	Long-Term Guideline Values
MAR	Managed Aquifer Recharge
MF	media-filtration
MMP	Monitoring and Management Plan
MNA	monitored natural attenuation
MW	Marine Water
NATA	National Association of Testing Authority
NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NPUG	Non-Potable Use Guideline
NZS	New Zealand Standard
PFAS	Per- and poly-fluoroalkyl substance
PFOS	Perfluorooctanesulfonic acid
PFOA	Perfluorooctanoic acid

PFHxS	Perfluorohexanesulfonic acid
PL	Prediction Limits
PQL	Practical Quantification Limit
PSH	phase separated hydrocarbons
QA/QC	Quality Assurance/Quality Control
RO	reverse osmosis
ROWS	Run Off Water Storage
RSA	Residue Storage Area
SAQP	Sampling and Analysis Quality Plan
SMP	Site Management Plan
SGV	Short-Term Guideline Values
TA	Total Alkalinity
TCE	trichloroethene
TD	Total Depth
TDS	Total Dissolved Solids
TPH	total petroleum hydrocarbons
TRH	total recoverable hydrocarbons
UF	ultra-filtration
UHPRO	ultra-high-pressure reverse osmosis
UPL	Upper Prediction Limits
USEPA	United States Environmental Protection Agency
WWTP	Wastewater Treatment Plant

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	micrometres
cm	centimetres
km	kilometres
m	metres
mm	millimetres
Mass	
µg	micrograms
g	grams
kg	kilograms
mg	milligrams
t	metric tonnes
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	microlitres
cL	centilitres
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
Aluminium	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
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
Moscovium	Mc
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
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

1 Introduction

Alcoa of Australia Limited (Alcoa) curtailed production in 2024 at its Kwinana Refinery, with alumina production ceasing in the third quarter of 2024; however, Alcoa continued operating the refinery circuit for the purposes of water inventory management. The Alcoa Facility operated a closed water circuit and was a net consumer of water that incorporated surface water and groundwater from the Alcoa Facility. In September 2025, Alcoa announced that the Refinery will permanently close and will therefore have a surplus of water that requires management into the future.

As part of Alcoa's integrated water management strategy, Alcoa is evaluating source water segregation and treatment options with a view to recharge treated water via aquifer infiltration, up to 3.5 GL/yr (or 400 kL/h) of this water into the Tamala Limestone aquifer.

Alcoa is seeking to infiltrate treated water at the O&P area, on the western boundary of the Open residue storage area (RSA) into the Tamala Limestone aquifer. As part of this process, it is understood that the contaminated sites Auditor (CS Auditor) and the Department of Water and Environmental Regulation (DWER) would like to understand whether the introduction of this water into the aquifer could impact the alkaline plume beneath the refinery (or other existing third party groundwater plumes) and/or have any adverse impacts on downgradient environmental receptors. The Monitoring and Management Plan (MMP) presents a framework to evaluate risks during the operational phase of infiltrating treated water into the Tamala limestone aquifer.

1.1 Feasibility Study

As part of the feasibility study, an infiltration risk assessment (refer to as the Commissioning/Operating Risk Assessment or CORA) was developed to evaluate the safe and effective infiltration of water into the Tamala Limestone aquifer. Specifically, the CORA outlined the groundwater quality treatment process and target water quality to be infiltrated and presented the most effective location for the project to occur while managing environmental risks and complying with regulatory requirements. To help meet the objectives of the project, a staged approach to better ascertain the feasibility and degree of difficulty (likely effort needed to achieve public health and environmental approvals from DWER) was undertaken. This was achieved by using the assessment framework set out in the Guidelines:

- Australian Guidelines for Water Recycling: Managed Aquifer Recharge (National Health and Medical Research Council [NHMRC], Environmental Protection and Heritage Council [EPHC], and Natural Resource Management Ministerial Council [NRMMC], 2009);
- Policy – Managed aquifer recharge in Western Australia (DWER, 2021); and
- Guideline – Water and environmental considerations for managed aquifer recharge operations in Western Australia (DWER, 2021a).

Specifically, this involved a staged process of project development and assessment, which included a pre-commissioning risk assessment, a short-term field trial, and a final evaluation of infiltration location and design. These stages are summarised briefly below, with a comprehensive evaluation provided in the CORA (EHS Support, 2025a).

1.1.1 Pre-Commissioning Risk Assessment

In order to determine design considerations, a risk assessment was completed to identify potential risks and establish appropriate management and monitoring to ensure these risks are low and acceptable. The risk assessment was undertaken in three parts:

- Adopting a semi-quantitative risk assessment outlined in the Managed Aquifer Recharge (MAR) Guidelines (NRMMC–EPHC–NHMRC, 2009);
- Undertaking a risk assessment defined in the Government of Western Australia Risk Assessment Guideline Part V, Division 3, *Environmental Protection Act 1986*, December 2020 (DWER, 2020); and
- Undertaking a semi-quantitative risk assessment that uses a contaminant mass flux assessment, and any potential impact the activity may have on contaminated sites.

The risk assessment concluded that there are no activities associated with infiltration that were ranked as a high or extreme risk for the project. This reflects the minor and temporary nature of the activity, and the application of appropriate management and mitigation measures.

1.1.2 Short-Term Field Trial

To validate the risk assessment outcomes, a short-term field trial was completed. The objectives of the field trial were to understand the degree of mounding underneath and adjacent to the proposed infiltration trenches (i.e., O&P area) and to update a regional numerical groundwater model, which has assisted in mitigating risks.

The field trial was completed for approximately 14 days, with a total infiltration volume of 14,400 kL and a water supply rate of between 12.5 L/sec and 30 L/sec. During the field trial, groundwater levels were measured in sentinel monitoring bores and the results incorporated into the regional numerical groundwater flow model to assist with model calibration. The results of the field trial and numerical model simulations indicated that infiltration of treated water is a feasible option to manage surplus treated water across the Alcoa Facility. Further information on the field trial is provided in Section 4.5 of the CORA (EHS Support, 2025a).

1.1.3 Infiltration Trench Location

The numerical groundwater model was used to evaluate potential locations and mechanisms for infiltration of treated water into the Tamala Limestone. The primary objective of the modelling exercise was to understand the hydraulic impacts to potential environmental receptors for a range of infiltration rates at various locations across the O&P area and proximal locations to the Open RSA. This facilitated a risk-based approach allowing the identification of the most feasible site for an infiltration scheme.

A total of five locations were initially sited by Alcoa, selected based on logistics, infrastructure, and proximity to receptors. Of the five locations, the O&P area was selected as the preferred infiltration site for the following reasons:

- The area of land is highly disturbed (i.e., base of the quarry), meaning there is no disturbance of existing vegetation.
- The majority of the infiltrated water avoids environmental and third-party receptors and eventually travels underneath the coastal Safety Bay Sands aquifer, where the majority remains in the Tamala Limestone as it moves underneath Cockburn Sound.
- The area avoids adverse impacts on downgradient known sites of potential contamination.
- At Long Swamp, groundwater levels in the Tamala Limestone adjacent the Swamp may increase by up to 0.27 m, however, the water levels in the Swamp itself will likely remain unchanged as this increase in hydraulic gradient only results in an additional flux to Long Swamp of 344 KL/yr, or (1.7%) from its baseline condition.

- At a distance of 20 m, groundwater mounding is less than 1 m, and this reduces to 0.30 m at a distance of 700 m away from the infiltration trench.
- Terrestrial vegetation remains unimpacted.

The modelling outputs and the final infiltration trench design are provided in detail in Appendix B of the CORA (EHS Support, 2025a).

1.2 Project Plan

Alcoa has committed to commissioning the water treatment plant in July 2026. Prior to infiltrating treated water, Alcoa will first undertake a Commissioning Phase (Phase 1) in which the water treatment plant will run continuously and discharge permeate back into the Run-off Water Storage (ROWS) Pond.

During Phase 1, testing of the permeate from the water treatment plant will be conducted for a period of two weeks to validate that compliance water quality criteria can be achieved. The program of works will include high-frequency sampling for a comprehensive analytical suite (refer **Section 3.4.2**). The water treatment plant may be commissioned prior to approval of infiltration and as a result the samples collected will be of unhardened water (the milk of lime addition to increase calcium content is part of the infiltration scope).

It is noted that it is highly likely that infiltration will start with Reverse Osmosis permeate only, and then condensate from the Mechanical Vapour Recompression (MVR) plants will be blended with permeate and discharged. The same two-week commissioning process will be used for the MVR Plants, and no new water source will be infiltrated prior to demonstrating that the water quality meets the specification.

Following completion of the Commissioning Phase and confirmation that the plant is producing treated water that is consistently compliant with the quality criteria described in this document, Alcoa will commence infiltration of treated water in the infiltration trenches located at the O&P area (Operational Phase). In the Commissioning Phase (where the water treatment plant is being ramped up and tested), the treated water will be discharged back to the ROWS Pond and/or reused for residue area management activities. In the Operational Phase, the combination of continuous monitoring (electrical conductivity [EC], pH) and plant operational parameters (pressures and flows) will be used to ensure the water treatment plant is operating correctly and supported by both on-site and third-party analytical testing. This MMP relates to the Operational Phase of the project, noting that there is reference to the Commissioning Phase in certain sections of this Plan.

1.3 Water Treatment Plant

The water treatment plant is designed to treat approximately 400 kL/hr with a feed in total alkalinity of 10 g/L (this will include mixing of Low and High Total Alkalinity (TA) water, as shown on **Figure 1-1**). Due to the highly impacted nature of the feed in water, the water treatment plant has been designed to ensure that it is a robust system that is capable of achieving the optimum water quality for infiltration. There will be some variation in permeate quality within a narrow range and a set upper bound.

A process overview of the water treatment plant is provided in **Figure 1-1**, and the intent of each of the process units is summarised in **Table 1-1**.

Table 1-1 Summary of Each Process Unit

Stage	Process Unit	Purpose
1	**Neutralisation**	Feed water pH is expected to be elevated and will require adjustment to facilitate treatment. The neutralisation unit has three primary functions: • Removal of caustic alkalinity to allow membrane technologies to be utilised; • Precipitation of aluminium as aluminium hydroxide and/or dawsonite, as aluminium is a scaling element in membranes; and • pH adjustment to promote insolubility of the specific organics in the feed water.
2	**Solids Separation**	The precipitation triggered by the neutralisation process generates large quantities of aluminium hydroxide and/or dawsonite that needs to be removed. Precipitate formed during the neutralisation process undergoes coagulation and flocculation to enhance settling of the particles. The blend is sent to Clarification for solids separation. Filtration follows to further polish the clarifier overflow. Media-filtration (MF) acts as a roughing filter to remove carry-over solids, with final polishing being done by Ultra-filtration (UF).
3	**Reverse Osmosis**	The reverse osmosis (RO) unit's primary function is removal of Total Dissolved Solids (TDS) from the filtered water. The proposed water treatment plant utilises four different types of RO units: • Pass 1 RO units for primary desalination of the filtrate from UF. • Pass 2 RO units for further treatment (polishing) of product water from pass 1, high-pressure and ultra-high-pressure RO units. • High-pressure RO units (HPRO) for further treatment of reject water from pass 1 RO units. • Ultra-high-pressure RO units (UHPRO) for further treatment of reject water from HPRO units.
4	**pH adjustment**	RO permeate is expected to contain a high concentration of CO_2. Contacting the permeate with air results in "degassing" of the permeate. CO_2 returns to the gas phase, reducing the carbonic acid concentration in the permeate. The degassing step is completed before the polishing RO. Final adjustment will be done with caustic dosing after the polishing RO.

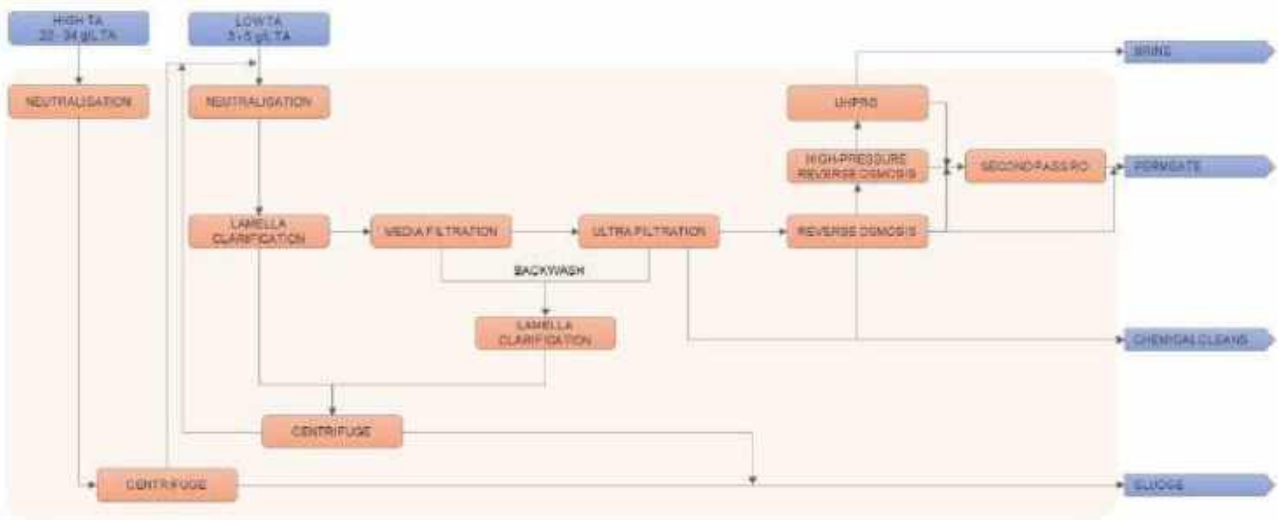


Figure 1-1 Process Flow Diagram

As part of the infiltration scope of work, the water treatment plant infrastructure (at the permeate tank) will be supplemented with mineralisation (hardening) chemical addition process. This chemical addition involves the dosing of milk of lime (a suspension of $Ca(OH)_2$ in water) to addresses the ionic imbalances which are due to the high purity of the permeate (and associated lack of divalent ions). The addition raises pH and adds Ca^{2+} and alkalinity, pushing the water towards calcite saturation and reducing its tendency to dissolve carbonate minerals in the receiving aquifer.

The addition of milk of lime will be conducted by the addition of a chemical dosing pump and two portable chemical storage totes (one in duty and one standby) to the water treatment plant configuration. The milk of lime will be added into the permeate tank or the discharge line from the permeate tank to the infiltration area, with the length of the piping run from the water treatment plant to the infiltration area supporting mixing. The dosing pump and chemical storage will be contained within the designated water treatment plant area.

1.3.1 MVR Plants for Evapo-Concentration

Mechanical Vapour Recompression plants will be used to treat water that is not amenable to reverse osmosis treatment (for example water containing very high EC and TA) or the brine stream produced by the operation of the water treatment plant. This includes:

- Stage 1 MVR Plant for water collected in RSA underdrainage systems and stored in F-surge Pond and Cooling Pond. This may also include brine overflows from the Lake Water Pond into the Cooling Pond.
- Stage 2 MVR Plant for brine from the water treatment plant and brine stored in the Lake Water Pond.

The process produces a concentrate stream which contains the impurities and ions from the feed stream and a high purity condensate stream. The condensate stream produced from this process is of higher quality than the permeate that is produced by the water treatment plant. It is proposed that this condensate stream will be discharged into the permeate storage tank, blended with permeate and similarly dosed with milk of lime (as described above) to mineralise the water prior to infiltration.

Mechanical vapour recompression has been selected as the technology for the management of these flows due to the high efficiency of the process where heat is recovered and reused within the system. A broad overview of the treatment process is:

- Feed water is heated to produce steam and a concentrate. A demister removes any droplets from the steam.
- MVR fans compress the steam further increasing latent heat.
- Compressed steam is passed through a heat exchanger where heat from condensing steam is recovered and used to heat feed water.
- The condensate from compressed steam is very pure water. This will comprise ~75% of feedwater.
- Ions are retained in the concentrate (~25% of feedwater), which will be transported to Alcoa's other refineries and used as a process input or sold commercially.

This process is similar to the current operations of the refinery where water from the ponds are evaporated producing a caustic alkaline residual product (CARP) which is subsequently trucked to Alcoa Pinjara's Alumina refinery as a product for use in the processing of bauxite. The key difference is the higher efficiency of the MVR plants which condense the steam to reuse the heat, while water evaporated in the refinery is vented to atmosphere.

Currently the plants are in the engineering design phase and Works Approval packages will be prepared for these plants. Based on the current schedule (dependent on regulatory approvals) the Phase 1 plant will be constructed/commissioned around Q3/Q4 2026, and Phase 2 Plant will be constructed and commissioned around Q3 2027.

2 Receptor Summary, Applicable Beneficial Uses, and Constituents of Concern

2.1 Receptor Overview

A summary of current and plausible beneficial uses of groundwater across the project site/activity area is presented in Table 2-2. The project site/activity area is defined in Section 2 of the CORA (EHS Support, 2025a). Details relating to the beneficial use and potential preclusions for groundwater use based on the conceptual site model developed for the site are included.

2.2 Relevant Receptors and Applicable Beneficial Uses for Consideration

Table 2-1 presents the beneficial uses that are considered relevant for the project and are applicable for setting trigger criteria based on the adopted Tier 1 screening criteria.

Table 2-1 Relevant Receptors and Applicable Beneficial Uses

Environmental Value	Relevant	Rationale
Drinking water (health and aesthetic)	NO	The activity area does not lie within a Public Drinking Water Source Area, their priority areas and protection zones. There are no known current users of groundwater in the Water Quality Impact Zone (WQIZ) that use groundwater for potable supply. Reticulated potable water supply is available within the activity area.
Water-dependent ecosystems and species Marine Ecosystem Protection	YES	Cockburn Sound is located downgradient of the activity area.
Water-dependent ecosystems and species Freshwater Ecosystem Protection	YES	Long Swamp is located downgradient of the activity area.
Stock and Agriculture (i.e., short-term irrigation)	YES	There are known registered groundwater users that extract groundwater for stock and agricultural use.
Non-Potable Use Water-based recreation (primary contact recreation)	YES	There are known registered groundwater users that may extract groundwater for other non-potable uses. It is noted that reticulated water supply is available within the activity area.
Industrial and commercial use	NO	There are no known registered groundwater users that extract groundwater for industrial and commercial use that would be negatively impacted by site activities. It is acknowledged that there are registered groundwater users for industrial use that are located cross gradient from site activities.
Terrestrial Vegetation	YES	Terrestrial vegetation is a realised beneficial use but is not subject to beneficial use screening criteria. Rather, numerical groundwater modelling will be undertaken and if groundwater as a result of the activity reduces to a depth less than 5 mbgl in areas where terrestrial vegetation occurs, an ecological assessment may be required. .

Table 2-2 Beneficial Uses Summary

Environmental Value	Description	Screening Criteria	Precluded Based on CSM	Precluded based on background salinity	Precluded based on criteria exceeding other ions in the background Tamala Limestone (refer Appendix A)
Drinking water (health and aesthetic)	Groundwater quality that is suitable for potable water supply.	• NHMRC ADWG 2011 Health. • PFAS NEMP 3.0 2025 – Human Health Drinking Water Quality Guideline Value. • NHMRC (2024) Australian Drinking Water Draft fact sheet on Per- and poly-fluoroalkyl substances (PFAS).	Precluded No known use of groundwater for drinking water purposes within the immediate vicinity of the project area	No Salinity is acceptable with potential blending with fresher water (i.e., from a tank)	Arsenic, lead, mercury, manganese, nitrate
Water-dependent ecosystems and species Marine Ecosystem Protection	Water quality that is suitable to protect the integrity and biodiversity of water-dependent ecosystems. This beneficial use encompasses: Protection of the integrity of riparian vegetation as it contributes to the health of water-dependent ecosystems and bank stability. That groundwater quality does not adversely affect surface water ecosystems. Ensures that groundwater quality does not adversely affect natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis to maintain their communities of organisms, ecological processes and ecosystem services; and Maintenance of fish passage.	• ANZG Toxicant Default Guideline Values – 95% Level of Species Protection – Marine Water. It should be noted that site-specific, risk-based criteria for Cockburn Sound have been developed by EHS Support and are currently under review by a Contaminated Sites Auditor. • WA EPA 2017 – Environmental quality criteria reference document for Cockburn Sound. • PFAS NEMP 3.0 2025 – 95% Species Protection – Slightly to Moderately Disturbed Systems. • EHS Support 2025b Cockburn Sound derived criteria.	Realised Cockburn Sound is a sensitive receptor of concern for Alcoa and DWER	No Average salinity is acceptable for this beneficial use	The following are ions in background groundwater quality that exceed the Marine water guidelines *95% species protection* Aluminium, arsenic, copper, iron, lead, manganese, mercury, zinc, PFOS
Water-dependent ecosystems and species Freshwater Ecosystem Protection		• ANZG Toxicant Default Guideline Values – 95% Level of Species Protection – Freshwater. • PFAS NEMP 3.0 2025 – 95% Species Protection – Slightly to Moderately Disturbed Systems. • PFAS NEMP 3.0 2025 – 99% Species Protection – High Conservation Value Systems.	Realised Long Swamp and Spectacles Wetland	No Average salinity is acceptable for this beneficial use	The following are ions in background groundwater quality that exceed the Freshwater guidelines *95% species protection* Aluminium, copper, lead, mercury, zinc

Environmental Value	Description	Screening Criteria	Precluded Based on CSM	Precluded based on background salinity	Precluded based on criteria exceeding other ions in the background Tamala Limestone (refer Appendix A)
Agriculture	Water quality that is suitable for agricultural activities such as stock watering and irrigation, as well as a range of other uses such as the irrigation of domestic gardens, commercial agriculture, parks and golf courses.	• ANZECC 2000a / ANZG 2024a and 2024b: Short-Term Guideline Values (STV) and Long-Term Guideline Values (LTV). • ANZECC 2000b Primary Industries.	Realised Based on TDS, neighbours can install a groundwater bore and use it to irrigate.	No Average salinity is acceptable for this beneficial use	Iron, manganese, mercury, phosphorus
Non-Potable Use Water-based recreation (primary contact recreation)	Water quality that is suitable for primary contact recreation (e.g., swimming, diving, water skiing, caving and spas), secondary contact recreation (e.g., boating and fishing) and for aesthetic enjoyment.	• DoH 2014, Contaminated sites ground and surface water chemical screening guidelines. • Non-potable groundwater use (NPUG). • NHMRC (2008) Guidelines for Managing Risks in Recreational Water for primary contact for bathing and swimming. • PFAS NEMP 3.0 2025 – Recreational Water Quality Guideline Value.	Realised Based on TDS, neighbours can install a groundwater bore and use it for water-based recreation.	No Average salinity is acceptable for this beneficial use	Aluminium, chloride, iron
Industrial and commercial use	Water quality that is suitable for industrial and commercial use.	• DoH 2014, Contaminated sites ground and surface water chemical screening guidelines. Non-potable groundwater use (NPUG).	Realised Based on TDS, neighbours can install a groundwater bore and use it for industrial and commercial use.	No Average salinity is acceptable for this beneficial use	Site-specific.
Terrestrial Vegetation[1]	Ensure groundwater levels do not increase or mound to adversely affect (such as water logging) Terrestrial Vegetation.	Screening criteria not applicable however, ecological assessments to occur if groundwater as a result of the activity shallows to a depth less than 5 mbgl in areas where terrestrial vegetation occur.	Not Applicable	Not Applicable	Not Applicable

Table Notes:
[1]Terrestrial Vegetation is a realised beneficial use, however not subject to beneficial use screening criteria. Rather numerical groundwater modelling will be undertaken and if groundwater as a result of the activity reduces to a depth less than 5 mbgl in areas where terrestrial vegetation occur, an ecological assessment may be required.

2.3 Other Areas of Concern

2.3.1 Alcoa Domains

Following the discovery of alkaline contamination of groundwater in the superficial aquifer underlying the Kwinana Alumina Refinery (mainly caustic soda [NaOH] and sodium carbonate [Na_2CO_3]), recovery bores were installed to recover alkali from the groundwater. The infiltration activities have the potential to increase the hydraulic gradient across the refinery and increase the flux of groundwater from the plume beneath the Refinery to Cockburn Sound. It is noted that the predicted flux change is minor, and the recovery bore network is suitable to mitigate any potential flux changes should they be identified.

In addition, localised groundwater plumes have been identified beneath the Open RSA. Bauxite residue leachate is suspected to have leaked from the Open RSA, with Area F identified as the primary source. Alkaline leachate in the older residue areas F is slowly leaking to the groundwater through defects in the clay liners, and potentially through low-rate, broad-scale seepage through larger areas of the clay liners. The Open RSA also contains a combination of recovery bores and monitoring bores to abstract alkali water and monitor existing groundwater impacts. The groundwater plume beneath the Open RSA has the potential to be mobilised by mounding from the infiltration program (i.e., radial flow from the infiltration trenches). It is noted that the infiltration trench is hydraulically downgradient of the Open RSAs, and the groundwater flow direction will not be modified (regional flow from the Open RSAs is still to the west/northwest, and the westerly horizontal hydraulic gradient is unlikely to change given a small increase in groundwater levels at the infiltration trenches.

2.3.2 Surrounding Contaminated Sites

In addition to the contamination underlying the refinery and Open RSA, multiple third-party sources of impacts have been observed in the superficial aquifer under the broader Kwinana Industrial Area (KIA). Investigations by DWER and its predecessor agencies have identified a range of contaminants in groundwater beneath and surrounding industrial premises, including:

- Petroleum hydrocarbons (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]; total petroleum hydrocarbons [TPH]);
- Chlorinated hydrocarbons (e.g., trichloroethene [TCE], perchloroethylene [PCE], vinyl chloride);
- Heavy metals (notably arsenic, lead, chromium);
- Nutrients (nitrate and ammonia); and
- Salinity, sulfate, and acid plumes associated with legacy waste discharge.

Several sites within the KIA are listed on the Contaminated Sites Register (CSR) maintained under the *Contaminated Sites Act 2003 (WA)*. These sites are classified under various risk categories including “contaminated – remediation required” and “contaminated – restricted use”, reflecting their potential to pose risks to human health and the environment if not properly managed.

As of July 2025, the CSR includes over 30 registered sites within the KIA, with contaminants of concern predominantly impacting groundwater quality. Of the 30 registered sites, there are seven sites (11 lots) that are located potentially cross-gradient or downgradient of the proposed infiltration area. In addition to these sites, DWER have advised of two other sites as ‘potentially contaminated, awaiting classification’. A Detailed Summary of Records (DSR) was submitted to DWER for each of the known sites. A summary of the contamination status of each of the sites is presented in **Table 2-3** and shown on **Figure 2-1**.

Table 2-3 Contaminated Sites Within the Activity Area of the Proposed Infiltration Trenches

Location	Status
30 and 32 Macedonia St Naval Base, WA,	Groundwater investigation results were submitted to DEC in August 2007 and showed the presence of Phase Separated Hydrocarbon (i.e., diesel) up to 0.33 m thick within groundwater at around 10 m depth, located within the southeast of the Site, corresponding to the location of the former underground fuel storage tank. Furthermore, low concentrations of Dissolved Phase Hydrocarbons were identified along the western perimeter of the Site, suggesting that there may be some off-site migration of groundwater contamination into adjacent land. Remediation, consisting of skimming and abstraction of hydrocarbon-impacted groundwater in 2006, moved over 100,000 litres of hydrocarbon-impacted water. Following the hydrocarbon remediation, the groundwater plume was confined to a 40 m² area, mostly in the southwest corner of 32 Macedonia St. The most recent GME report, issued in 2012, stated that the plume was stable and evidence of MNA of the plume had been identified. The site has not been reclassified from Contaminated- Restricted Use. The site is restricted to its current use as a commercial storage yard. A review of the data from the most recent available groundwater sampling event, completed in October 2012, found concentrations of hydrocarbons in groundwater localised under the site, including wells with evidence of Phase Separated Hydrocarbons (PSH) in three of the wells. Samples with PSH were not submitted for laboratory analysis. In addition to the presence of PSH, one of the onsite wells contained concentrations of hydrocarbon of TRH Fraction >C10-C16 exceeding the WHO (2008) NPUG equivalent screening criteria. Minor concentrations of metals exceeding adopted criteria were noted. All wells sampled downgradient of the plume had concentrations of hydrocarbons below the laboratory detection limit, indicating the plume remained localised under the site.
Lot 1 on Plan 24276 – Peron Quarry	The site and two adjacent land parcels were classified under the CS Act on 24 September 2007, constituting a source site (classified as contaminated – restricted use) and two affected properties (classified as potentially contaminated – investigation required). The site was a prescribed premises used to receive a buried fly ash waste in slurry form from the Kwinana Power Station. Contamination at the Site was identified in the form of barium, manganese, and heavy metals are present in fly ash within disposal ponds in the eastern part of the site and a groundwater plume is present downgradient of the disposal ponds, which are being controlled by groundwater abstraction at the site. The plume contains elevated concentrations of ammonium, aluminum, manganese, and heavy metals. Groundwater monitoring has been completed at the site since 1995, with the latest available from 2022. The most recent data shows the plume contains elevated concentrations of nutrients and metals. The elevated nutrient concentrations are considered representative of regional groundwater conditions and not as a result of the site's land use. The results of the groundwater monitoring concluded that the extent of the plume is understood and does not pose an unacceptable risk to human health or the environment/environmental values. 360 Environmental (2022) recommended to the contaminated sites auditor, the Perron Quarry site, should be reclassified to 'remediated – restricted use' (RRU) for commercial/industrial use only, with groundwater abstracted only for non-potable use only (i.e., not for drinking water). **In November 2023, the site was classified as remediated for restricted use.**
27 Weston St and a portion of Weston St Road Reserve, Naval Base, WA	The site was classified under the CS Act in July 2010, following the decommissioning of a fuel station that existed at the site from 1971-2009. Contamination was identified in the form of hydrocarbons in soil and groundwater from petrol or diesel during a contamination assessment. Hydrocarbon impacts were not identified in the top 3 m of the soil profile. Groundwater monitoring completed between 2015 and 2017 found concentrations of hydrocarbons in groundwater exceeding non-potable groundwater use criteria. An assessment of the groundwater plume found that MNA appeared to have been occurring since 2009. Based on the data, the site was not considered to pose an unacceptable risk to human health or the environment for its current use. **The site was reclassified as remediated for restricted use.**

Location	Status
	A review of the data from the most recent available groundwater sampling event, completed in March 2017, found concentrations of hydrocarbons in groundwater localised under the site, but no screening criteria were exceeded. Concentrations of arsenic, copper, nickel and zinc exceeded relevant assessment criteria. Exceedances were limited to high protection screening criteria for the Cockburn Sound.
2 Barter Road and Barter Road Reserve, Naval Base WA	2 Barter Street forms part of the Kwinana Power Station, known as the strategic oil reserves. The site was classified as under the CS Act in September 2008 due to the presence of hydrocarbon-impacted soils and groundwater. The site was classified as under the CS Act in September 2008 due to the presence of hydrocarbon-impacted soils and groundwater. The site has been reclassified multiple times since 2008 and most recently was **reclassified as remediated for restricted use in August 2025**. The hydrocarbon contamination was a result of spills during the ongoing operation of the power plant, including a release of hydrocarbons of 523,000L in 2012. A series of investigations and remediation works have been undertaken at the site since 2012. As of 2025, the contamination status at the site is localised hydrocarbon impacts in soil at the smear zone and a hydrocarbon plume in groundwater. The easternmost portion of 18 Barter Road and Barter Road Reserve are affected sites from 2 Barter Street, with the groundwater plume extending under these sites. An SMP is in place to manage the impacts remaining at the site. A review of the data from the most recent available groundwater sampling event, completed in May 2023, found concentrations of hydrocarbons in groundwater localised under the site, one of the onsite wells contained concentrations of hydrocarbon of TRH Fraction >C10-C16 exceeding the WHO (2008) NPUG Equivalent screening criteria. All wells sampled downgradient of the plume had concentrations of hydrocarbons below the laboratory detection limit, indicating the plume remained localised. In addition to the hydrocarbon concentrations, concentrations of PFAS were detected in the majority of wells beneath the site with concentrations exceeding the NEMP PFAS 99% specifies protection criteria and draft drinking water criteria in some wells. The source of the PFAS in groundwater is not clear and may be the result of the industrial use of the KWI.
Lot 22 Weston Street, Naval Base, WA	Lot 22 Weston Street was historically used as a Coal Fired Power Station. The site was classified as under the CS Act in 2008 due to the presence of hydrocarbon-impacted soils and groundwater. The site was classified due to multiple potentially contaminating activities such as coal and bottom-ash storage, waste-oil storage, fuel systems, transformers and workshops. Soil and groundwater investigations undertaken between 2003 and 2007 identified widespread contamination across several parts of the site, including heavy metals, hydrocarbons and petroleum hydrocarbons in both surface soils and groundwater. Several bottom-ash ponds required excavation and off-site disposal. Some areas underwent remediation and validation, results confirmed remaining impacts relating to oil-contaminated horizons discovered during earthworks for new ash ponds. Contamination was also detected in other precincts, including fuel forwarding systems, step-up transformer areas and waste-oil storage areas, with investigations revealing localised but significant hydrocarbon staining and heavy-metal impacts. A review of the data from recent available groundwater sampling events, three plumes at the site. The plumes were identified at the former oil bulk storage area (most recent event 2021), former turbine halls (most recent sampling event in 2024) and former coal stockyard (most recent sampling event in 2022). A summary of the contaminants identified in concentrations exceeding assessment criteria for each plume is presented below • Contaminants beneath the former coal stockyard exceeded the assessment criteria for PFAS compounds and hydrocarbons, including areas of Light Non-Aqueous Phase Liquid (LNAPL). The source of the LNAPL was believed to be the historical site use. PFAS was identified in concentrations exceeding the 99% Marine Protection Criteria and drinking water criteria. Two distinct PFAS signatures were identified in the groundwater beneath the site, one of which appeared to be associated with a former fire training facility formerly at the site; the source of the second PFAS signature was not identified.

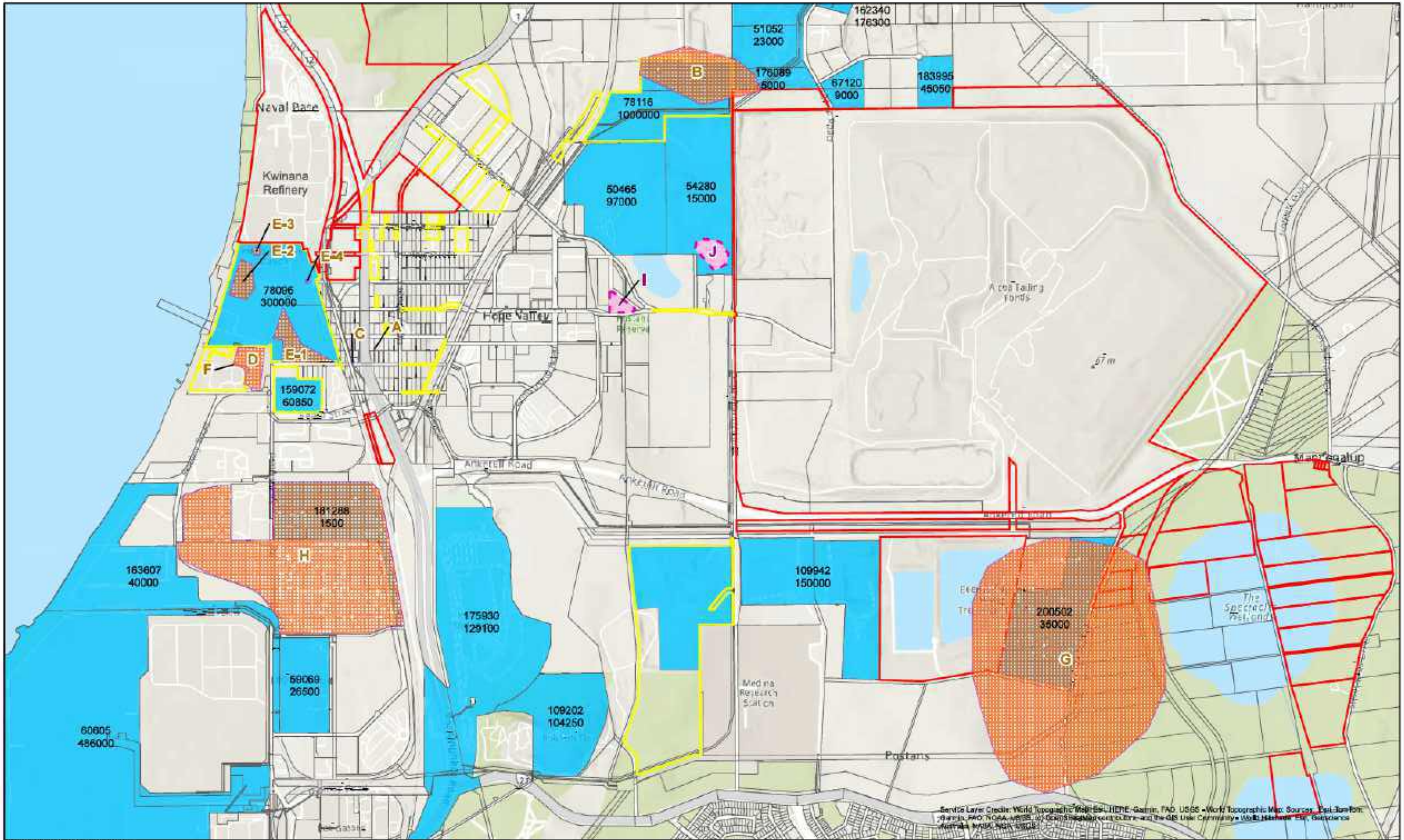
Location	Status
	• The investigation completed at the former turbine halls identified concentrations of hydrocarbons (NPUG and recreational criteria), heavy metals (95% Marine Protection Criteria), PFAS (99% Marine Protection Criteria) and TDS (NPUG). The source of the heavy metals and hydrocarbons was concluded to be the use of the turbine halls, while the source of the PFAS was not identified. • Contaminants beneath the former oil bulk storage area exceeded the assessment criteria for PFAS compounds and hydrocarbons, including areas of LNAPL and concentrations of PFOS exceeding the 99% Marine and Freshwater Protection Criteria. The hydrocarbons in groundwater were linked to a former oil sump from the site's historical land use. No source for the PFAS compounds was identified during the investigation.
Lot 3000 on Plan 46763 and 18 Barter Road and Barter Road Reserve, Naval Base WA	The site was classified under the CS Act in September 2008, due to the site's operation as a coal-fired fired power station. Several investigations were carried out as part of the redevelopment of the site as the Perth Seawater Desalination Plant. The investigations determined the presence of hydrocarbons in groundwater. 18 Barter Street, formally part of the Kwinana Power Station, for ancillary uses such as ash storage, workshops and offices. Portions of the site were subject to groundwater and soil investigation between 2003 and 2005 before the site was developed into the Perth Seawater Desalination Plant. The Site has been subject to ash relocation and soil remediation, which was successfully validated. Following the remediation and validation of the site it was **reclassified as remediated for restricted use** in 2009 with restrictions on groundwater abstraction due to the presence of the hydrocarbon plume. A review of the data from the most recent available groundwater sampling event, completed in February 2009. found concentrations of hydrocarbons in groundwater localised under the site, but no screening criteria were exceeded. Concentrations of copper, nickel and mercury exceeded relevant assessment criteria. Exceedances were limited to high protection screening criteria for the Cockburn Sound.
143 McLaughlin Road, Postans, WA	The site was first classified under the CS Act by the department in August 2014. It is currently classified as *"Possibly contaminated - investigation required"*. These reasons for classification have been updated to reflect additional technical information submitted to the department by January 2025. The site has operated as the Kwinana WWTP since the 1970s, with additional solid waste recycling activities occurring on the site. Numerous investigations into the soil and groundwater have been undertaken at the site, which have identified elevated concentrations of nutrients and PFAS in groundwater beneath the site. Detailed Hydrological Investigation, including a tracer study, confirmed that a complete pathway is present between infiltrated treated wastewater and the Spectacles Wetland, with the groundwater plume being delineated from the infiltration area to a discharge zone on the eastern shore of the Spectacles northern lake. A review of the data from the most recent available groundwater sampling event, completed in January 2022, found that concentrations of PFAS were detected in the majority of wells beneath the site, with concentrations exceeding the NEMP PFAS 99% protection criteria and draft drinking water criteria in some wells. Concentrations of phosphorous were detected in concentration exceeding irrigation criteria. Some concentrations of metals, aluminium and iron were found to exceed NPUG create noting these criteria are aesthetic only. Other metals found to exceed criteria include arsenic and lead exceeding drinking water criteria with copper, nickel and lead exceeding ecological criteria.

Location	Status
Lot 2 on deposited plan 419343 Lot 301 on plan 407762 Lot 302 on plan 407762 Lot 252 on deposited plan 415974	The sites were classified as part of a parcel consisting of 12 sites, which were classified as **Contaminated – Restricted Use** under the CS Act in November 2008. The sites form part of a large commercial industrial complex, including a blast furnace powerhouse, steel merchant, raw material and product storage, production waste disposal, including the disposal of slag, dusts and demolition waste, mixed and putrescible wastes. Soil investigations were carried out between 2000 and 2003. The soil investigations identified widespread industrial slag and cinders within the Site that were found to contain slightly elevated concentrations of heavy metals exceeding ecological investigation but below health investigation levels. A leachability study conducted on the impacted soils found no evidence of risk to the underlying groundwater from the leaching of soil contamination. A groundwater investigation identified the widespread presence of nitrate contamination at concentrations exceeding Marine Water criteria, although no potential contaminants were detected above ten times the drinking water criteria.
Lot 521 on deposited plan 300764 (awaiting classification – Recognised by DWER as potentially contaminating sites)	DWER has advised that the site is classified as a potentially classified site that is awaiting classification. DWER has reported that there is limited information, but the classification is currently based on the site's historical use as a power station. A review of available historical aerial photography shows that the power station was constructed on the site between 1953 and 1961. The duration of the operations at the site is not known, but the majority of the infrastructure, such as the powerhouse, was removed from the site in 2011. There are no known investigations at the site. The contaminants of concern for power station sites in accordance with DWER (2021b) are metals, hydrocarbons, PFAS and polychlorinated biphenyls (PCB). These contaminants are reported to be associated with fly ash and bottom ash, which may have been produced during the operation of the power stations include metals, TDS and sulfates (DWER, 2021b).
Lot 170 on Plan 300773 (awaiting classification – Recognised by DWER as potentially contaminating sites)	DWER has advised that the site is classified as a potentially classified site that is awaiting classification. DWER has reported that there is limited information, but the classification is currently based on the site having buried fly ash. A review of available historical aerial photography shows that the fly ash began being buried at the southern portion of the site between 1970 and 1974. The wider site has been used as a sand quarry since 1970. The burial of the ash at the site ceased between 1983 and 1985 when the cell being used to contain the ash was capped. The remainder of the site has continued to be used as a quarry until the present. The contaminants of concern related to fly ash in accordance with DWER (2021b) are metals, TDS and sulfates.

The potential mobilisation and migration of existing groundwater plumes associated with infiltration has been discussed in the CORA and considered when developing the monitoring network as part of this MMP. The risk of mobilising any downgradient and cross gradient groundwater impacts was determined to be low.

2.3.1 Potentially Unknown Surrounding Contaminated Sites

In addition to the known contaminated sites, there is a potential that other contamination sources may be present cross- and downgradient of the proposed infiltration area. To assess the potential and associated risks associated with these sites, a LotSearch review of potentially contaminating land uses and aerial photographs and a qualitative risk assessment were completed (refer to CORA). No high-risk sites were identified; however, several medium-risk sites were identified within the area of groundwater influence. The increased groundwater flux is considered to be relatively minor, and unlikely to impact plume migration in these areas. The locations of these medium risk sites that were within the mounding areas are included on **Figure 2-1**.



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User Name: Danny.Barnes; Date and Time Printed: 9/02/2026 9:11 PM; Document Path: Y:\GIS_Projects\Alcoa\Kwinana\20251003_WTP_Infiltration_and_Aquifer_Injection_Trial\03_Mapping\Figures\NEW FIGURES\NEW FIGURES.aprx

Offsite Plume Extents and Potential Medium-Risk Sites

0 0,25 0,5 1 1,5 2 km

[Page Size: A3]

LEGEND

- Cadastre
- Groundwater License Holders
- Offsite Plume Extents
- DWER Potentially Contaminated Sites - Awaiting Classification
- Medium-risk sites identified in the Hydraulic Impact Zone
- Alcoa Property Boundary

Monitoring and Management Plan

EHS Support

Figure 2-1

CREATED BY:	D. Barnes
APPROVED BY:	T. Davis
PROJECT REF. NO:	PTY.06099
MAP PROJECTION:	Transverse Mercator
GRID/DATUM:	GDA2020 MGA Zone 50
SCALE:	1:20,273
AERIAL IMAGE SOURCE:	ESRI Basemap

2.4 Constituents of Concern

The following sections present the framework adopted to confirm the constituents of concern that will form the primary water quality suite to evaluate potential risks to receptors during the operational phase of infiltration.

This process of screening of constituents was developed in consultation with the CS Auditor who has historically been engaged in assessments involving evaluation of the beneficial uses of groundwater within the Kwinana area. Non-Potable Use Guidelines (NPUG) were selected as the appropriate screening criteria as the Tamala Limestone in this area is not in a designated potable water supply area, and water usage in the area is focused on industrial water supply. The NPUG ensures that the treated water will not pose a health risk to downgradient non-potable users. The screening process is considered conservative as the assessment was conducted on influent water quality (neutralised and clarified) only with the reverse osmosis treatment process producing effluent with order of magnitude reductions in minor ion concentrations.

2.4.1 Analysis of Neutralised Feed Water to Support Constituents for Treatment

The comprehensive analytical suite reported in the neutralised feed during the water treatment plant pilot trial (February and April 2025) were evaluated through a stepwise screening process to identify constituents that require further treatment and form part of the analytical suite for the MMP. The neutralised feed is representative of the proposed neutralised feed to the full-scale water treatment plant (i.e., from the recovery bore network at the Refinery and RSAs, the underdrainage system at the Open RSA and stormwater). The screening process progressed as follows:

1. Constituents that were not detected above the LOR in the neutralised feed water were removed.
2. Constituents that were below the NPUG were highlighted for removal. An additional screening of these constituents was completed against the background UPL. Where the constituent was below the NPUG, however above the background UPL, it was retained. Otherwise, it was removed.
3. Where the NPUG were absent, constituents below the background UPL for the Tamala Limestone in the neutralised feed, were removed.

The following methods were also applied to defining constituents to form part of the analytical suite for the MMP.

1. Physical properties, that is non ion specific parameters were removed.
2. Gross alpha and gross beta are not considered further. Solids interference in the analysis reports concentrations slightly above UPLs. Post filtration, the concentrations are an order of magnitude below.
3. A number of rare earth minerals (hafnium, indium, niobium, tantalum and zirconium) were detected at very low concentrations in the neutralised raw water feed to the plant. There are no relevant criteria for these constituents and subsequent steps in the process support their removal below analytical reporting limits.
4. Nitrogen oxides were also detected and have no background UPL or NPUG criteria, but these constituents were assessed through analysis of ammonia, nitrate, nitrite and TKN, with ammonia and TKN retained in the assessment above.
5. N-Nitrosodimethylamine, phenol, thiosulfate and sulfide all have low concentrations and there are no relevant beneficial use criteria. All compounds will be removed by the membrane treatment technologies, are readily biodegradable and/or will rapidly oxidise and react.
6. PFBS (max of 0.0053µg/L), PFHpA (max of 0.029 µg/L), PFHxA (max of 0.064 µg/L), PFPeS (max of 0.0023 µg/L) were all detected in background samples but background UPLs were not calculated. The concentrations in the neutralised raw water feed were generally consistent with background. These PFAS compounds are included in the standard PFAS analytical suite and in combination with PFOS, PFOA and PFHxS will be demonstrated to be absent in the treated effluent from the water

treatment plant as part of commissioning testing. PFOS, PFOA, and PFHxS have been included in the screening process below as there are criteria for relevant beneficial uses.

Constituents remaining after the completion of this refinement process were identified as relevant contaminants of potential concern and were evaluated through a secondary screening process.

The analytical results reported for the pilot trial are presented in **Appendix B.** These samples were analysed by NATA accredited laboratory MPL Laboratories in Perth, and therefore the LORs for each constituent are considered appropriate for comparison to screening criteria.

2.4.1.1 Constituents Below LORs

There were 123 constituents that had concentrations below the LOR across all three samples of the neutralised feed water, and these are presented in **Table 2-4.** The full dataset is provided in **Appendix B.**

Table 2-4 Constituents Not Detected in the Neutralised Feed from Pilot Trial

Chemical Name	Neutralised Feed Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
4:2 FTS	0/3	Below
6:2 FTS	0/3	Below
8:2 FTS	0/3	Below
10:2 FTS	0/3	Below
2,4,5-Trichlorophenol	0/3	Below
2,4,6-Trichlorophenol	0/3	Below
2,4-Dichlorophenol	0/3	Below
2,4-Dimethylphenol	0/3	Below
2,4-Dinitrophenol	0/3	Below
2,6-Dichlorophenol	0/3	Below
2.3.4.5 & 2.3.4.6-Tetrachlorophenol	0/3	Below
2-Chlorophenol	0/3	Below
2-Cyclohexyl-4,6-Dinitrophenol	0/3	Below
2-Methylphenol (O-Cresol)	0/3	Below
2-Nitrophenol	0/3	Below
3- & 4-Methylphenol	0/3	Below
4,6-Dinitro-2-Methylphenol	0/3	Below
4-Chloro-3-Methylphenol	0/3	Below
4-Nitrophenol	0/3	Below
Aldrin	0/3	Below
Alkalinity, Carbonate (As CaCO3)	0/3	Below
Alkalinity, Hydroxide (As CaCO3)	0/3	Below
alpha BHC (Alpha Hexachlorocyclohexane)	0/3	Below
Alpha Endosulfan	0/3	Below
Azinphos- methyl (Guthion)	0/3	Below
Barium	0/3	Below
Beryllium	0/3	Below
beta BHC (Beta Hexachlorocyclohexane)	0/3	Below
Beta Endosulfan	0/3	Below
Bismuth	0/3	Below
Bromophos-ethyl	0/3	Below
Calcium	0/3	Below
Carbon disulfide	0/3	Below

Chemical Name	Neutralised Feed Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
Cerium	0/3	Below
Cesium	0/3	Below
Chlorpyrifos	0/3	Below
Chlorpyrifos Methyl	0/3	Below
cis-Chlordane	0/3	Below
Cobalt	0/3	Below
Coumaphos	0/3	Below
delta BHC (Delta Hexachlorocyclohexane)	0/3	Below
Diazinon	0/3	Below
Dichlorvos	0/3	Below
Dieldrin	0/3	Below
Dimethoate	0/3	Below
Dinoseb	0/3	Below
Disulfoton	0/3	Below
Dysprosium	0/3	Below
Endosulfan sulfate	0/3	Below
Endrin	0/3	Below
Endrin Ketone	0/3	Below
Erbium	0/3	Below
Ethion	0/3	Below
Europium	0/3	Below
Fenamiphos (Nemacur)	0/3	Below
Fenitrothion	0/3	Below
Fenthion	0/3	Below
Ferrous Iron	0/3	Below
Gadolinium	0/3	Below
gamma BHC (Lindane)	0/3	Below
gamma-Chlordane	0/3	Below
Germanium	0/3	Below
Hardness (As CaCO3)	0/3	Below
Heptachlor	0/3	Below
Heptachlor epoxide - isomer a	0/3	Below
Heptachlor epoxide - isomer b	0/3	Below
Hexachlorobenzene	0/3	Below
Holmium	0/3	Below
Lanthanum	0/3	Below
Lead	0/3	Below
Lithium	0/3	Below
Lutetium	0/3	Below
Malathion	0/3	Below
Magnesium	0/3	Below
Manganese	0/3	Below
Mercury	0/3	Below
Methane	0/3	Below
Methidathion	0/3	Below
Methoxychlor	0/3	Below
Mevinphos	0/3	Below
Mirex	0/3	Below
Neodymium	0/3	Below
N-EtFOSE	0/3	Below

Chemical Name	Neutralised Feed Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
N-EtFOSA	0/3	Below
N-EtFOSAA	0/3	Below
N-MeFOSE	0/3	Below
N-MeFOSA	0/3	Below
N-MeFOSAA	0/3	Below
P,P'-DDD	0/3	Below
P,P'-DDE	0/3	Below
P,P'-DDT	0/3	Below
Parathion, ethyl	0/3	Below
Parathion, methyl	0/3	Below
Pentachlorophenol	0/3	Below
PFBA	0/3	Below
PFDS	0/3	Below
PFDA	0/3	Below
PFDoDA	0/3	Below
PFHpS	0/3	Below
PFNA	0/3	Below
FOSA or PFOSA	0/3	Below
PFPeA	0/3	Below
PFTeDA or PFTA	0/3	Below
PFTrDA	0/3	Below
PFUnDA	0/3	Below
Phorate	0/3	Below
Phosalone	0/3	Below
Praseodymium	0/3	Below
Rhenium	0/3	Below
Ronnel	0/3	Below
Samarium	0/3	Below
Scandium	0/3	Below
Silver	0/3	Below
Sulfite (As SO_3)	0/3	Below
Sum of organochlorine pesticides	0/3	Below
Tantalum	0/3	Below
Tellurium	0/3	Below
Terbium	0/3	Below
Thallium	0/3	Below
Thulium	0/3	Below
trans-Chlordane	0/3	Below
Ytterbium	0/3	Below
Yttrium	0/3	Below

2.4.1.2 Remaining Constituents with Sample Detect Counts and Screening Assessment

There were 62 constituents that had concentrations above the LOR in at least one sample of the neutralised feed water, and these are presented in Table 2-5. These samples were also screened against the NPUG guidelines and/or background Tamala Limestone UPLs. The full dataset is provided in Appendix B.

Table 2-5 Constituents Detected in the Neutralised Feed from Pilot Trial and Screening Assessment

Chemical Name	Neutralised Feed (dissolved sample) Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
Alkalinity, Total (As CaCO3)*	3/3	Not applicable (refer footnote)
Aluminium	3/3	**Exceed**
Ammonia as N	3/3	**Exceed**
Antimony	3/3	Below
Arsenic	3/3	**Exceed**
Biochemical Oxygen Demand (BOD) *	3/3	Not applicable (refer footnote)
Boron^	3/3	**Retained refer to footnote**
Cadmium	3/3	Below
COD - Chemical Oxygen Demand*	3/3	Not applicable (refer footnote)
Chloride	3/3	**Exceed**
Chromium	3/3	Below
Copper	3/3	Below
Cyanide	1/3	**Exceed**
Fluoride^	3/3	**Retained refer to footnote**
Gallium&	3/3	**Retained refer to footnote**
Gross alpha particle activity#	3/3	Not applicable (refer footnote)
Gross beta particle activity#	3/3	Not applicable (refer footnote)
Hafnium%	2/3	No UPL or NPUG Criteria
Iron	2/3	Below
Indium%	1/3	No UPL or NPUG Criteria
Molybdenum	3/3	**Exceed**
Nickel^	3/3	**Retained refer to footnote**
Nitrate	1/3	Below
Niobium%	3/3	No UPL or NPUG Criteria
Nitrite	2/3	Below
Nitrogen	1/1	Below
Nitrogen oxides, NOx%	2/2	No UPL or NPUG Criteria
N-Nitrosodimethylamine%	1/3	No UPL or NPUG Criteria
PFBS%	3/3	No UPL or NPUG Criteria
PFHpA%	3/3	No UPL or NPUG Criteria
PFHxA%	3/3	No UPL or NPUG Criteria
PFHxS@	1/3	**Retained refer to footnote**
PFOS@	1/3	**Retained refer to footnote**
PFOA@	3/3	**Retained refer to footnote**
PFPeS%	1/3	No UPL or NPUG Criteria
Phenol%	3/3	No UPL or NPUG Criteria
Phosphate	3/3	**Exceed**
Phosphorus	2/3	Below
Potassium	3/3	Below
Rubidium	3/3	Below
Selenium	3/3	**Exceed**
Silicon	1/3	Below
Sodium	3/3	**Exceed**

Chemical Name	Neutralised Feed (dissolved sample) Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
Strontium	1/3	Below
Sulfate	3/3	Below
Sulfide%	1/3	No UPL or NPUG Criteria
Sulfur	3/3	Below
Tantalum%	1/3	No UPL or NPUG Criteria
Thiosulfate%	1/3	No UPL or NPUG Criteria
Thorium	3/3	**Exceed**
Tin	1/3	**Exceed**
Titanium	3/3	Below
TDS	3/3	**Exceed**
Total Carbon*	3/3	Not applicable (refer footnote)
Total Inorganic Carbon*	3/3	Not applicable (refer footnote)
Total Kjeldahl Nitrogen	2/2	**Exceed**
Total Organic Carbon*	3/3	Not applicable (refer footnote)
Tungsten	3/3	Below
Uranium	3/3	Below
Vanadium	3/3	**Exceed**
Zinc	2/3	Below
Zirconium%	3/3	No UPL or NPUG Criteria

Table Notes:

* Represents physical parameters and are not considered further.

Gross alpha and gross beta are not considered further. Solids interference in the analysis reports concentrations slightly above UPLs. Post filtration the concentrations are an order of magnitude below.

^ Boron, fluoride and nickel – retained because even though constituent is below NPUG, it is above the UPL.

& No dissolved phase UPL available, therefore the total phase UPL has been adopted.

@ No UPL available, however screening criteria for other beneficial uses available, therefore retained.

% A number of rare earth minerals (hafnium, indium, niobium, tantalum and zirconium) were detected at very low concentrations in the neutralised raw water feed to the plant. There are no relevant criteria for these constituents and subsequent steps in the process support their removal below analytical reporting limits (consistent with background- refer **Table 2-6**). Nitrogen oxides were also detected and have no background UPL or NPUG criteria, but these constituents were assessed through analysis of ammonia, nitrate, nitrite and TKN, with ammonia and TKN retained in the assessment above. N-Nitrosodimethylamine, phenol and thiosulfate and sulfide all have low concentrations and there are no relevant beneficial use criteria. All compounds will be removed by the membrane treatment technologies, are readily biodegradable and/or will rapidly oxidise and react (noting that if any sulfide or thiosulfate oxidation byproducts are present, they would react with the milk of lime producing gypsum).

PFBS (max of 0.0053µg/L), PFHpA (max of 0.029 µg/L), PFHxA (max of 0.064 µg/L), PFPeS (max of 0.0023 µg/L) were all detected in background samples but background UPLs were not calculated. The concentrations in the neutralised raw water feed were generally consistent with background (**Table 2-7**). These PFAS compounds are included in the standard PFAS analytical suite and in combination with PFOS, PFOA and PFHxS (refer **Section 2.4.1.3**) will be demonstrated to be absent in the treated effluent from the water treatment plant as part of commissioning testing. PFOS, PFOA, and PFHxS have been included in the screening process below as there are criteria for relevant beneficial uses.

Table 2-6 Neutralised Feed – Dissolved Trace Metal Summary (mg/L)

Constituent	Detect Count	LOR	Maximum Concentration
Hafnium	2/3	0.001	0.01
Indium	1/3	0.001	0.0012
Niobium	3/3	0.001	0.0048
Tantalum	1/3	0.001	0.0057
Zirconium	3/3	0.001	0.021

Table 2-7 Neutralised Feed and Background Tamala Limestone Concentrations for Select PFAS Compounds (µg/L)

Constituent	Neutralised Feed Detect Count	Neutralised Feed Concentration	Tamala Limestone Background Detect Count	Tamala Limestone Background Maximum Concentration
PFBS	3/3	0.0026 – 0.0071	15 / 32	0.0053
PFHpA	3/3	0.00078 – 0.0015	21 / 32	0.029
PFHxA	3/3	0.00092 – 0.0022	28 / 32	0.064
PFPeS	1/3	0.0017	2 / 32	0.0023

2.4.1.3 Included Constituents in the Infiltration Risk Assessment and MMP

Based on the framework presented above the following constituents have been included for analysis in the infiltration assessment (**Table 2-8**); there are a total of 25 remaining of the total 190 constituents analysed.

Where there is justification to remove a constituent based on the framework above, but the constituent is considered a key parameter for groundwater assessment, the constituent has been kept in the ongoing dataset. These are indicated with '*' in the table below.

Table 2-8 Constituents to be Included in the Infiltration Assessment

Chemical Name	Neutralised Feed Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
Aluminium	3/3	Exceed
Ammonia as N	3/3	Exceed
Arsenic	3/3	Exceed
Boron	3/3	Exceed
Calcium*	0/3	Below
Chloride	3/3	Exceed
Cyanide	1/3	Exceed
Fluoride*	3/3	Below
Gallium*	3/3	Below
Magnesium*	0/3	Below
Molybdenum	3/3	Exceed
Nickel*	3/3	Below
Nitrate*	1/3	Below
PFHxS*	1/3	Below
PFOS*	1/3	Below
PFOA*	3/3	Below

Chemical Name	Neutralised Feed Detect/Sample Count	Neutralised Feed Screening Outcome (NPUG or Background UPL)
Phosphate	3/3	Below
Potassium*	3/3	Below
Selenium	3/3	Exceed
Sodium	3/3	Exceed
Sulfate*	3/3	Exceed
Thorium	3/3	Exceed
Tin	1/3	Exceed
TDS	3/3	Exceed
Total Kjeldahl Nitrogen	2/2	Exceed
Vanadium	3/3	Exceed

Table Notes:
* indicates constituents with justification to remove, however they have been retained as a key parameter for further assessment. It is proposed that initial testing of the plant on commissioning will include these parameters but that on confirmation that concentrations in the neutralised feed are below criteria that these constituents will be removed from the long-term monitoring program.

2.4.2 Commissioning Phase

As discussed in **Section 1.2**, during the Commissioning Phase, the water treatment plant will be operational for a period of approximately 14 days to demonstrate that the minimum compliance criteria, set by Proxa, for the relevant constituents can be achieved. During this Commissioning Phase (and the necessary time period for receipt of results and confirmation of acceptability) the treated water will not be discharged to the infiltration trench. These constituents and minimum compliance criteria are provided in **Table 2-9**.

The treated water will be sampled daily for a period of 14 days for a comprehensive analytical suite for a broad range of organic and inorganic constituents, as summarised in **Table 3-5**. It is noted that this suite is much more comprehensive than the constituents associated with the plant compliance criteria; however, it is considered necessary during this commissioning phase to confirm if additional constituents need to be incorporated into the compliance monitoring program. The framework presented in **Section 2.4.1** will be adopted.

The treated water will be used for spray evaporation and dust suppression during the commissioning period. Where water produced is surplus to demand, the water will be discharged back into the ROWS feedwater pond.

2.4.3 Operational Phase – Constituents of Relevance Road Map

To determine which constituents are to be included in the Operational Phase analytical suite (referred hereon as the primary water quality suite) that forms part of this MMP, the following was undertaken:

1. The permeate compliance constituents, as presented in **Table 2-9**, were compared to background Tamala Limestone Upper Prediction Limits (EHS Support, 2025b). It should be noted that this screening process is also partially undertaken in the framework presented in **Section 2.4.1**, however the first screening process also screens against NPUG (rather than just background UPLs) where they exist. Where the concentration of a constituent in the permeate water is less than the background UPL, this will be flagged and potentially removed from the analytical suite, based on the results of the screening assessment against the Tier 1 screening criteria.
   It is noted that the background UPLs will be supplemented by baseline data collected from new and existing sentinel and delineation bores (likely June 2026) that will be installed within the proposed infiltration areas. It is expected that baseline will be combined with the background Tamala Limestone dataset, and the UPLs recalculated.
2. Of the remaining constituents in the permeate water, screen these against the relevant Tier 1 screening criteria and site -specific Environmental Quality Guidelines (EQGs) for Cockburn Sound (refer to **Table 2-2**). Where the concentration of a constituent in the permeate water is less than all Tier 1 screening criteria, remove from the analytical suite.
3. Incorporate constituents that may be important to assess advective and dispersive geochemical mixing and attenuation processes and aquifer mineralisation reactions regardless of the outcomes of (1) and (2).

The following sections present a comparison of the permeate water quality data against the background Tamala Limestone UPLs and the relevant Tier 1 screening criteria. The outcomes from this screening assessment will be the constituents that comprise the primary water quality suite that will be adopted for the MMP.

2.4.4 Permeate Water Quality

The design composition of the feed in water and the permeate water quality, as determined by Proxa (the water treatment plant vendor), is presented in **Table 2-9**. It should be noted that several constituents have already been removed from further assessment as the concentrations were below the detection limit in the neutralised feed water (refer **Section 2.4.1** and **Appendix B**).

Treatment will reduce the concentrations of some constituents in the raw water (non-neutralised) feed by up to four orders of magnitude, and the percent removal of most constituents is >97%. All reasonable efforts will be made to reduce the concentrations of constituents to below the Australian drinking water guidelines where criteria exist.

Table 2-9 Raw Water Feed and Permeate Quality

Parameter	Unit	10 g/L feed concentration	Permeate Quality – Proxa	Percent Removal from Reverse Osmosis plant
Aluminium	mg/L	555	0.15	99.98
Ammonia as N	mg/L	0.21*	0.10	50.00
Ammonia	mg/L	0.25*	0.12	50.00
Arsenic	mg/L	1.5	0.010	97.80
Boron#	mg/L	0.650 - 1.000	0.900	10 to 29.69
Calcium	mg/L	8	1.0	98.72
Chloride	mg/L	350	17.5	99.99
Cyanide	mg/L	0.014*	0.0007	95.00

Parameter	Unit	10 g/L feed concentration	Permeate Quality – Proxa	Percent Removal from Reverse Osmosis plant
Fluoride	mg/L	10	0.5	97.80
Gallium	mg/L	4.30	0.005	97.80
Magnesium	mg/L	1	0.1	98.72
Molybdenum	mg/L	2.350	0.09	97.80
Nickel	mg/L	0.010	0.002	97.80
Nitrate	mg/L	37.6	2.0	97.80
PFOS	µg/L	ND (ND)^	<0.01	99.99
PFOA	µg/L	0.011 (0.033)^	<0.01	99.99
PFHxS	µg/L	0.00021 (0.00063)^	<0.01	99.99
Phosphate	mg/L	0.92	0.02	96.50
Potassium	mg/L	18	1.2	97.80
Selenium	mg/L	0.635	0.010	97.80
Sodium	mg/L	5,040	150	97.50
Sulfate	mg/L	410	20.0	97.78
Thorium	mg/L	0.0032*	0.00007	97.80
Total Dissolved Solids	mg/L	15,560	600	96.81
Total Kjeldahl Nitrogen	mg/L	10*	0.5	95.00
Tin	mg/L	0.005	0.002	97.80
Vanadium	mg/L	2.3	0.010	97.80

Table Notes:
µg/L – micrograms per litre
mg/L – milligrams per litre
PFHxS – Perfluorohexanesulfonic acid
PFOA – Perfluorooctanoic acid
PFOS – Perfluorooctanesulfonic acid
* Maximum concentration adopted in absence of Proxa data
# Uncertainty exists on Boron feed concentrations due to change in pH in plant resulting increase in solubility. Based on poor rejection efficiency a safety factor has been applied.
^ PFOS, PFOA and PFHxS results from the Clarifier Overflow during the Pilot Trial. PFAS was not analysed on the raw feed water. The Pilot Plant had a Total Alkalinity input of approximately 3 g/L, therefore the PFAS results have been multiplied by a factor of 3.

2.4.5 Comparison Against Tamala Limestone Background UPLs

Environmental thresholds were calculated based on data from nine background monitoring bores screened in the Tamala Limestone formation. These bores were sampled four times; November 2024, February 2025, May 2025, and August 2025. All calculated UPLs have been determined to have acceptable suitability to be used as environmental thresholds and are considered suitable for detecting changes in conditions over time (Appendix A).

The first stage of the road map included comparing the permeate water quality and the Background Tamala Limestone UPLs (Table 2-10). Aluminium, boron, fluoride, gallium, molybdenum, nickel, selenium, sodium, tin, vanadium concentrations in the permeate water exceed the Background Tamala Limestone UPLs.

Table 2-10 Permeate Water Quality Compared to Background Tamala Limestone UPLs

Parameter	Unit	Permeate Quality - Proxa	Background Tamala Limestone UPL	Exceeds Background UPL
Aluminium	mg/L	0.15	0.04	YES
Ammonia as N	mg/L	0.10*	0.18	
Ammonia	mg/L	0.12*	0.22	
Arsenic	mg/L	0.010	0.03	
Boron	mg/L	0.900	0.13	YES
Calcium	mg/L	1.0/50@	350	
Chloride	mg/L	17.5	222	
Cyanide	mg/L	0.0007*	0.004	
Fluoride	mg/L	0.5	0.41	YES
Gallium	mg/L	0.005	0.002	YES
Magnesium	mg/L	0.1/5.0@	40	
Molybdenum	mg/L	0.09	0.007	YES
Nickel	mg/L	0.002	0.002	YES
Nitrate	mg/L	2.0	47.4	
PFOS	µg/L	<0.01	0.00066^	
PFOA	µg/L	<0.01	0.01^	
PFHxS	µg/L	<0.01	0.0043^	
Phosphate	mg/L	0.02	0.03	
Potassium	mg/L	1.2	10.1	
Selenium	mg/L	0.010	0.004	YES
Sodium	mg/L	150	129	YES
Sulfate	mg/L	20.0/50.0@	640	
Thorium	mg/L	0.00007*	0.002	
TDS	mg/L	600	1093	
TKN	mg/L	0.5*	1.2	
Tin	mg/L	0.002	0.001	YES
Vanadium	mg/L	0.010	0.009	YES

Table Notes:
µg/L – micrograms per litre; mg/L – milligrams per litre
CORA – Commissioning/Operational Risk Assessment
PFHxS – Perfluorohexanesulfonic acid; PFOA – Perfluorooctanoic acid; PFOS – Perfluorooctanesulfonic acid
UPL – Upper Prediction Limit
* Calculated based on maximum concentration
^ Background UPL not calculated and therefore maximum concentration presented. Analysis was on the unfiltered sample; potential interferences will require a higher reporting limit (i.e., <0.01ug/L)
@ Estimates of post milk of lime dosing ion concentrations have been included in table and are shown as secondary values (i.e. 1/10). This impacts on values for Calcium, Magnesium and Sulfate.

2.5 Permeate Water Quality Screening Assessment

The second stage of the road map included comparing the permeate water quality with all relevant Tier 1 screening criteria (**Table 2-11**). Aluminium, molybdenum, selenium, and vanadium concentrations in the permeate water exceeded at least one of the Tier 1 screening criteria. For reference, permeate water has also been screened against the Australian Drinking Water Guidelines (ADWG); if the permeate quality is equal to or above the ADWG it is highlighted yellow. Alcoa will make all reasonable efforts to reduce the concentrations of constituents to below the ADWG where criteria exist. Additionally the surface water quality reported from three samples collected in Long Swamp in August and November 2025, and the dissolved phase groundwater quality range (period 2024 to 2025) from upgradient (from Long Swamp) Tamala Limestone groundwater bores G-005 and N-019S are presented for reference in **Table 2-11**.

It is noted that the screening assessment is considered to be conservative, as it is based on the quality of feed water, prior to reverse osmosis treatment. Once operational, condensate from MVR Plants will be blended with permeate. The MVR Plant treatment process involves concentrating the ions in a concentrate stream and producing a low TDS water condensate stream with properties consistent with distilled water. Assessment of data provided by equipment providers indicates that the condensate will have a lower TDS than the permeate and condensate is expected to be of better quality than permeate. This will be confirmed by testing condensate during the commissioning phase for the MVR Plants. MVR treatment is a proven technology for the production of a low TDS condensate stream and is effective at concentrating both inorganic and organic constituents in a small volume while producing a high-volume condensate stream of water vapour that has very low ion concentrations.

Table 2-11 Permeate Water Quality Compared to Screening Criteria

Parameter	Unit	Permeate Quality – Proxa	Long Swamp Water Quality (August 2025)	Upgradient of Long Swamp Tamala Limestone Groundwater Quality (G-005 and N-019S)	Screening Criteria					ADWG (2011) Version 4.0 updated June 2025) Potable Water Use
					DoH (2014) non-potable groundwater use	ANZECC (2000) Short term irrigation water	ANZG (2018) 95% Species Protection Freshwater	EHS Support (2025) Cockburn Sound Criteria (Moderate Ecological Protection)	Exceeds at least 1 screening criterion	
Aluminium	mg/L	0.15	0.03	<0.01	0.2	20	0.055	0.086	YES	0.200*
Ammonia as N	mg/L	0.10#	<0.004 - 0.04	<0.005 – 0.090	0.41	NC	0.74	1.2		0.41*
Ammonia	mg/L	0.12#	<0.005 – 0.05	<0.006 – 0.109	0.5	NC	0.9	1.46		0.5*
Arsenic	mg/L	0.010	0.062 – 0.078	<0.001 – 0.0021	0.1	2	0.013	0.017		0.010
Boron	mg/L	0.900	0.38 – 0.48	0.027 – 0.071	40	NC	0.940	5.1		4.00
Calcium	mg/L	1.0/50.0@	74 – 76	83 – 120	NC	NC	NC	NC		NC
Chloride	mg/L	17.5	2530 - 2570	75 – 130	250	NC	NC	NC		250
Cyanide	mg/L	0.0007#	NA	<0.004 – 0.0044	0.8	NC	0.007	0.004		0.08
Fluoride	mg/L	0.5	0.2	<0.1 – 0.12	15	2.0	1.7	NC		1.50
Gallium	mg/L	0.005	NA	<0.001	NC	NC	NC	1.1		NC
Magnesium	mg/L	0.1/5.0@	139 – 141	9.9 – 12	NC	NC	NC	NC		NC
Molybdenum	mg/L	0.09	<0.001	<0.001 – 0.0014	0.5	0.05	0.034	6.20	YES	0.050
Nickel	mg/L	0.002	0.005 – 0.006	<0.001	0.2	2.0	0.011	0.20		0.020
Nitrate	mg/L	2.0	<0.01	11 – 24	500	NC	29	121.6		50
PFOA	µg/L	<0.01	0.0027 – 0.0030	<0.0002 – 0.01	10	NC	220	220		0.2
PFOS	µg/L	<0.01	0.0017 – 0.0023	<0.0002 – 0.00066	2	NC	0.48	0.13		0.008
PFHxS	µg/L	<0.01	0.00088 – 0.0013	<0.0002 – 0.0043		NC	NC	NC		0.03
Phosphate	mg/L	0.02	0.022 – 0.027	0.01 – 0.02	NC	NC	NC	NC		NC
Potassium	mg/L	1.2	53 – 54	2.8 – 11	NC	NC	NC	NC		NC
Selenium	mg/L	0.010	<0.001 – <0.01	0.0012 – 0.0018	0.1	0.05	0.011	0.01	YES	0.004
Sodium	mg/L	150	1460 – 1480	38 – 83	NC	NC	NC	NC		180*
Sulfate	mg/L	20.0/50.0@	415	33 - 95	1000	NC	NC	NC		250
Thorium	mg/L	0.00007#	NA	<0.0005	NC	NC	NC	NC		NC
TDS	mg/L	600	4460 - 7040	360 – 610	NC	NC	NC	NC		600*
TKN	mg/L	0.5#	2.6 - 2.8	<0.1 – 0.57	NC	NC	NC	NC		NC
Tin	mg/L	0.002	NA	<0.001	NC	NC	NC	NC		NC
Vanadium	mg/L	0.010	0.0016 – <0.01	<0.001	NC	0.5	0.006	0.160	YES	NC

Table Notes:

NA – Not Analysed; NC – No Criteria

PFHxS – Perfluorohexanesulfonic acid; PFOA – Perfluorooctanoic acid; PFOS – Perfluorooctanesulfonic acid

* Aesthetic criteria

Calculated based on maximum concentration

@ Estimates of post milk of lime dosing ion concentrations have been included in table and are shown as secondary values (i.e. 1/10). This impacts on values for Calcium, Magnesium and Sulfate.

2.6 Constituents to be Included in the Primary Water Quality Suite

Table 2-12 presents a summary of the constituents that exceeded the Background Tamala Limestone UPLs and the Tier 1 screening criteria. It is noted that where a constituent exceeds the UPL but not the Tier 1 screening criterion (and vice versa), it will still be adopted in the primary water quality suite.

Table 2-13 presents the final primary water quality suite that will be adopted for the operational phase of the project. It is noted that general parameters have also been included as they provide important data to assess advective and dispersive geochemical mixing and attenuation processes and aquifer mineralisation reactions. Attenuation is an important component of the adaptive management approach.

Table 2-12 Screening Assessment Summary

Parameter	To be included in the primary water quality suite based on Background Tamala Limestone UPLs	To be included in the primary water quality suite based on Tier 1 screening assessment	Other ions to be included in the primary water quality suite to support assessment outcomes
Aluminium	Yes	Yes	
Ammonia			
Arsenic			Yes
Boron	Yes		
Calcium			Yes
Chloride			Yes
Cyanide			
Fluoride	Yes		
Gallium	Yes		
Magnesium			Yes
Molybdenum	Yes	Yes	
Nickel	Yes		
PFOA			
PFOS			
PFHxS			
Phosphate			
Potassium			Yes
Selenium	Yes	Yes	
Sodium	Yes		
Sulfate			Yes
Thorium			
TDS			Yes
TKN			
Tin	Yes		
Vanadium	Yes	Yes	

Table Notes:
PFHxS – Perfluorohexanesulfonic acid
PFOA – Perfluorooctanoic acid
PFOS – Perfluorooctanesulfonic acid
UPL – Upper Prediction Limit

Table 2-13 Constituents to be Included in the Primary Water Quality Suite

Suite	Constituent
General Parameters	pH, TDS, cations (Ca, K, Mg, Na) and anions (Cl, NO_3, SO_4, fluoride and alkalinity)
Metals	Al, As, B, Ga, Mo, Ni, Se, Sn, V
Other	Hardness

3 Monitoring and Management Plan

The overall goal of the MMP is to manage the downgradient flux and water quality of infiltrated water, ensuring that there are not unacceptable risks to human health, ecological receptors, and the environment. This MMP incorporates the knowledge gained from numerical groundwater modelling, investigations, and monitoring conducted at the site, and utilises the combination of early warning sentinel monitoring bores, delineation bores, and natural attenuation processes to provide a solution that is protective.

This MMP incorporates an adaptive management approach whereby monitoring data proximal to the infiltration trenches, and monitoring data proximal to receptors is utilised to inform infiltration rates with the fundamental goals of:

1. Maintaining downgradient groundwater quality and ensuring protection of human health and ecological receptors.
2. Maximising the efficiency of the infiltration trenches to ensure maximum infiltration and minimise mounding.
3. Ensuring that infiltration does not result in the exacerbation of groundwater conditions, including facilitating additional lateral spreading of existing groundwater plumes.
4. Maintaining downgradient geochemical conditions that are conducive to attenuation.

The concept of adaptive management is increasingly being adopted in Australia as a structured, iterative approach to environmental management. In the development of these adaptive management approaches, references are commonly made to United States Environmental Protection Agency (USEPA) guidance documents (USEPA, 2022; Interstate Technology Regulatory Council [ITRC], 2017; NRC, 2004; Williams et al. 2009).

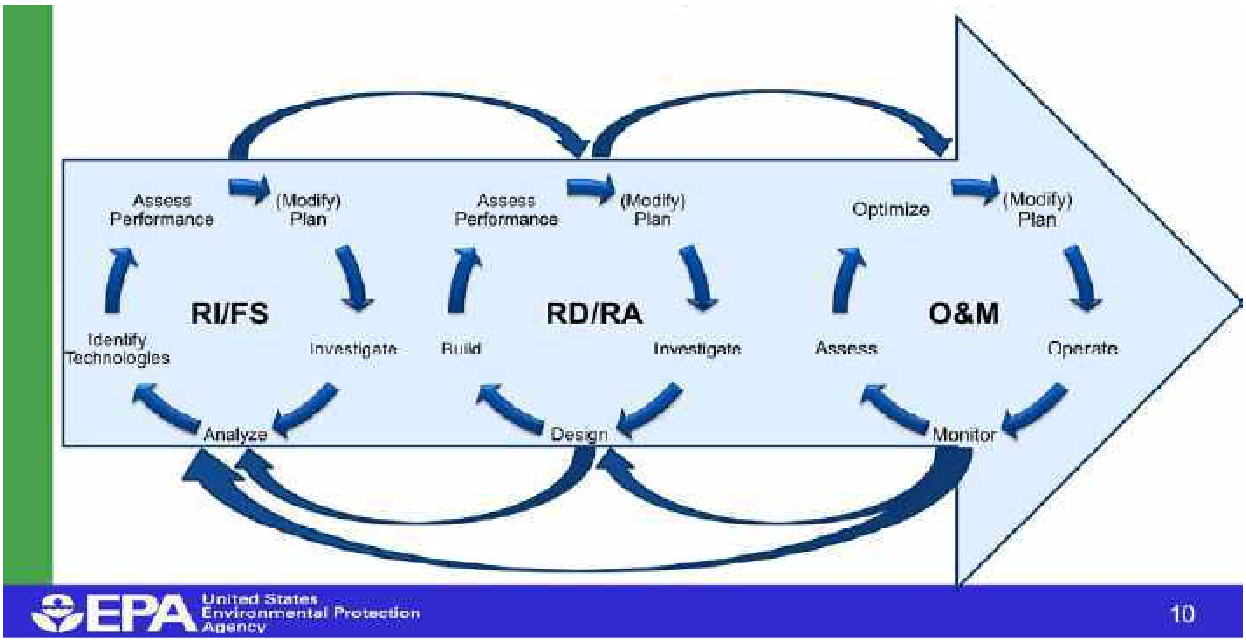


Figure 3-1 Adaptive Management Process – Project Lifecycle

Note: RI/FS = Remedial Investigation/Feasibility Study; RD/RA = Remediation Design/Remedial Application; O&M = Operations and Maintenance

In the context of this approach, monitoring bores upgradient of receptors and distinct areas of impacted groundwater will be monitored to assess the effectiveness of the infiltration trenches relative to the performance goals described above. A focus on management of flux will not lead to further degradation of the aquifer due to the magnitude of advective and dispersive mixing of permeate in the groundwater downgradient of the infiltration trenches.

Numerical groundwater modelling has been used to assess the potential impacts of infiltrating 3.5 GL/year across two infiltration trenches within the O&P area. Based on the design and size of these infiltration trenches, the modelling shows no significant change to downgradient flux.

The effectiveness of the infiltration trenches in controlling the flux of constituents and supporting downgradient advective and dispersive mixing will continue to be assessed by the targeted monitoring plan described below. In this context, this MMP establishes trigger levels for determining success, or for establishing further response measures where pre-determined risk levels are exceeded. Where considered necessary on the basis of monitoring results, additional management response measures are taken, and adjustments are made to the MMP to complete the feedback loop and allow for the ongoing effective management of groundwater impacts. These response measures and adaptive management mechanisms are discussed in **Section 4**.

3.1 Objectives

The primary purpose of the selected monitoring bores is to provide data to support optimisation of infiltration in accordance with this plan's goals and demonstrate that, in combination with downgradient advective and dispersive mixing, flux and associated potential risks are being effectively managed. More specifically, this includes monitoring designed to support achievement of the following objectives:

- Ensure that permeate and condensate water quality is suitable for infiltration.
- Ensure that groundwater levels are monitored enabling identification of mounding beneath the infiltration trench, existing groundwater plumes, and Long Swamp to ensure downgradient receptors are protected.
- Ensure that groundwater quality is monitored enabling identification of potential risks to environmental values.
- To optimise performance and minimise downgradient flux,
- Assess the effectiveness of the MMP in protecting potential receptors, i.e., Long Swamp, Cockburn Sound, existing third-party groundwater users.
- Assess the effectiveness of the MMP in mitigating third-party groundwater plume migration.
- Monitor the natural attenuation of constituents in groundwater and refine the understanding of geochemical and biological (organic constituents only) attenuation processes.
- Assess water quality parameters and determine if water quality is changing over time in response to changes in operations.

Each of these monitoring objectives and the associated program of works is described in the sections below. The selection of monitoring bores was based on an evaluation of the groundwater flow system and impacted groundwater dynamics.

3.2 Monitoring and Identification of Potential Risks to Environmental Receptors

Table 3-1 outlines each source/activity, the corresponding potential receptor, and the strategy for monitoring. Further detail on the monitoring network design is discussed in **Section 3.3**. It should be noted that the monitoring program will be reviewed after one year of operation and adjusted based on a risk assessment framework. We anticipate that any changes to the monitoring program will be reviewed by the CS Auditor.

Table 3-1 Monitoring Strategies for Identified Potential Receptors

Source/Activity	Potential Receptor/s	Monitoring Strategy	Purpose
Treated Water – Operational Phase	All receptors	Treated Water Quality Overview – It is noted that the concentration of some constituents in the permeate water will be higher than background/baseline UPLs and/or the adopted Tier 1 screening criteria. The permeate water quality achieved will be based on the practical limits of the water treatment plant. The MMP provides an adaptive management framework with a comprehensive monitoring network to evaluate potential changes in groundwater quality downgradient of the infiltration trenches. **Commissioning Phase Monitoring of Permeate and Condensate** – sample the treated water daily for a two-week period. Determine the flow weighted average concentration. The analytical suite will be based on the framework as described in **Section 2**. **Operational Phase Monitoring of Permeate** – continuous monitoring of pH and EC of the treated water at the Water Treatment Plant. If the water quality is within the compliance criteria for pH and EC, then the minor ions will also meet compliance criteria (**i.e.**, EC <925 µS/cm*). If the pH and/or EC concentrations are above these criteria, the water treatment plant permeate will be directed to the ROWS pond. Alcoa will still collect weekly samples of the water discharged to the infiltration trenches. A 30-day flow weighted average concentration of ions will be determined and accessed against the compliance criteria.	Ensure water quality meets licence conditions and is protective of downgradient receptors.
Long Swamp	Freshwater ecosystems	Sampling of the surface water at Long Swamp up to 3 discrete locations monthly over a period of 6 months. This dataset will be used to develop a baseline understanding and differentiate between surface water and groundwater types.	Allows for an assessment of complete migration pathways should monitoring indicate a potential for groundwater interaction and/or baseflow to Long Swamp during infiltration activities.
Infiltration Trenches	Tamala Limestone aquifer (Upper and Lower) Third-party groundwater users (stock, agriculture and non-potable supply) Third-party existing groundwater plumes Long Swamp and Freshwater ecosystems Cockburn Sound and marine ecosystems Refinery groundwater plume	**Pre Infiltration Program (baseline and natural variation understanding)** Collection of 4-6 months of groundwater levels across the R1/R2 Sentinel Bores, R3 Delineation Bores, proximal delineation bores and existing monitoring bores to establish natural variation. This will be in the form of automated pressure transducer dataloggers and manual gauging. Collection of a minimum of four rounds of sampling across the R2 Sentinel Bores, R3 Delineation Bores, proximal Delineation Bores and nominated existing monitoring bore network for a comprehensive analytical suite to establish baseline conditions. **Operational Phase** **Early Warning – R1 Sentinel Bores** High frequency hourly groundwater levels recorded using automated pressure transducers, as an indicator of groundwater mounding. Pressure transducer data will be uploaded twice a day.	Define the lateral and vertical flux in combination with infiltration data. Demonstrate the stability of the groundwater and compliance with relevant beneficial use criteria and/or baseline. Allow for screening of groundwater quality data against relevant beneficial use criteria and/or baseline. Demonstrate that geochemical conditions support advective and dispersive mixing and attenuation. Assess potential risks to downgradient receptors and the environment.

Source/Activity	Potential Receptor/s	Monitoring Strategy	Purpose
		Manual gauging of groundwater levels monthly. **Early Warning – R2 Sentinel Bores** High frequency hourly groundwater levels recorded using automated pressure transducers, as an indicator of groundwater mounding. Manual gauging of groundwater levels monthly. High frequency (monthly) monitoring using sodium, EC and pH as an indicator of groundwater impacts. Discrete sampling events of primary water quality parameter suite of the R2 Sentinel Bores to evaluate impacts to receptors where sodium, EC and pH show a non-optimal condition. **Early Warning – R3 Delineation Bores** Manual gauging of groundwater levels quarterly. Discrete sampling events of primary water quality parameter suite (three-monthly) of the R3 Delineation Bores to evaluate impacts to receptors. **Compliance – Receptor Delineation Bores** The following receptor delineation bores are defined (refer **Section 3.3.1**). • Long Swamp Delineation Bores (LSD) • Peron Quarry Delineation Bores (TPD). It is noted that there are three existing monitoring bores owned by Peron Quarry that may be utilised instead. This will be dependent on access agreements and suitability. • Southern Site Delineation Bores (N series bores) • Northern Site Delineation Bores (G series bores) • Refinery Plume Delineation Bores (KW series and B2052S/D only)) • RSA ABC Plume Delineation Bores (B2057S/D and B2062S only) • Other Unknown Contaminated Sites Delineation Bores (B2052S/D, B2056S/D, B2061S/D) Manual gauging of groundwater levels quarterly for the first 12 months of operation. Discrete sampling events of primary water quality parameter suite (annually) in line with MMP. In the instance that a trigger level or a non-optimal condition is also observed in R2 Sentinel Bores and/or R3 Delineation Bores, sampling frequency to increase based on the response actions (refer **Section 4**).	

Table Notes

* A conversion factor of 0.65 has been applied to convert EC to TDS for water at Kwinana. The EC–TDS conversion factor is dependent on the ionic composition and purity of the water and is therefore not fixed. Water with lower ionic strength or a different ion balance may warrant a lower conversion factor. For example:

- ~0.5 is typically applied to deionised or very low-salinity water.
- Waters with low sodium and calcium concentrations or mixed ionic compositions commonly fall within the 0.55–0.60 range.

A site-specific conversion factor can be determined from paired EC and laboratory TDS data collected during the commissioning phase and applied prior to the commencement of infiltration.

3.3 Proposed Monitoring Program and Monitoring Network Design

The MMP has established a monitoring program focused on managing downgradient risks and mitigating offsite fluxes to downgradient properties and receptors through an adaptive management approach. The monitoring data within and proximal to areas of infiltration is utilised with the fundamental goals of:

1. Maintaining downgradient groundwater quality and ensuring protection of human health and ecological receptors.
2. Ensuring that infiltration does not result in the detrimental impacts to ecological receptors and water-dependent ecosystems such as Long Swamp.
3. Ensuring that the infiltration does not result in the exacerbation of groundwater conditions, including impacting areas of known contamination.
4. Maintaining downgradient geochemical conditions that are conducive to advective and dispersive geochemical mixing and attenuation.

3.3.1 Monitoring Bore Locations and Purpose

The monitoring bore network has been developed based on the outcomes of the numerical groundwater modelling, the identification of potential migration pathways, and the location of receptors and areas of interest. The monitoring network will comprise existing Alcoa-managed groundwater bores and new monitoring bores to be installed specifically for the purposes of meeting the project objectives.

Table 3-2 summarises the type of new monitoring bores to be included in the monitoring network, the purpose of each type of bore, and the indicative construction details. The final construction of each new bore will be based on drilling observations, including water strike and lithological profile. **Table 3-3** provides a summary of the new monitoring bore IDs and location information, noting that these locations may be moved should there be accessibility constraints. **Table 3-4** provides a summary of the existing monitoring bore IDs and location information that will also form part of the monitoring network.

The proposed monitoring bore network is shown on **Figure 3-2**. It should be noted that the bore condition and aquifer screening, as well as its involvement in other monitoring objectives (i.e., GMMP), have also been considered when selecting existing monitoring wells from Alcoa's expansive bore network.

Table 3-2 New Monitoring Bore Type and Purpose

Monitoring Bore Type	Purpose and Rationale	Indicative Bore Construction
R1 Sentinel Bores	Early Warning, hydraulics only	3 m screen, screened from 0.5 m above watertable to 2.5 m below watertable.
R2 Sentinel Bores	Early Warning, water quality indicator parameters (sodium, EC, pH)	Two bores at each location (nested). Shallow nest 3 m screen starting from 0.5 m above water table. Deep nest screened in basal 3 m of aquifer It should be noted that both shallow and deep screened monitoring bores have been selected at each location to allow for an analysis of lateral and vertical changes in hydraulics and chemistry.

Monitoring Bore Type	Purpose and Rationale	Indicative Bore Construction
R3 Delineation Bores (western boundary of O&P area)	Early Warning Assessment of water quality (primary water quality parameter suite) prior to leaving Alcoa site boundary	Two bores at each location (nested). Shallow nest 3 m screen starting from 0.5 m above water table. Deep nest screened in basal 3 m of aquifer It should be noted that both shallow and deep screened monitoring bores have been selected at each location to allow for an analysis of lateral and vertical changes in hydraulics and chemistry.
Long Swamp Delineation Bores	Direct Receptor Site (hydraulics and primary water quality parameter suite)	Three new bores (LSD-A to C) and existing bore N-019S/D. 3 m screen Screened from 0.5 m above water table. Screened intervals to be based on site specific information including depth to groundwater and lithological profile.
Refinery Plume Delineation Bores	Direct Receptor Site (hydraulics and primary water quality parameter suite)	Existing bores KW027S/D, KW068I, B2052S/D No new bores proposed
Peron Quarry Delineation Bores	Direct Receptor Site (hydraulics)	Three new bores (TPD-A to C). 3 m screen Screened from 0.5 m above water table. Screened intervals to be based on site specific information including contaminant type, depth to groundwater and lithological profile. It is noted that there are three existing monitoring bores owned by Peron Quarry that may be utilised instead. This will be dependent on access agreements and suitability.
Southern Site Delineation Bores	Direct Receptor Site (hydraulics and primary water quality parameter suite)	Existing bores N-002S/D, N-003S/D, N-004S/D No new bores proposed
Northern Site Delineation Bores	Direct Receptor Site (hydraulics and primary water quality parameter suite)	Existing bores G-010S/D No new bores proposed
RSA ABC Plume Delineation Bores	Direct Receptor Site (hydraulics and primary water quality parameter suite)	Existing bores B2057S/D and B2062S No new bores proposed
Other Unknown Contaminated Sites Delineation Bores	Direct Receptor Site (hydraulics and primary water quality parameter suite)	Existing bores B2052S/D, B2056S/D, B2061S/D No new bores proposed

Table 3-3 Additional Monitoring Bores to be Installed to Supplement the Existing Monitoring Bore Network

Purpose	Bore ID	Easting MGA94 (m)	Northing MGA94 (m)	Nominal PVC Diameter (mm)
R1 Sentinel Bore	O-R1-001	387950.0869	6437310.303	50
R1 Sentinel Bore	O-R1-002	387929.0045	6437260.841	50
R1 Sentinel Bore	O-R1-003	387929.0045	6437208.135	50
R1 Sentinel Bore	O-R1-004	387929.8154	6437125.427	50
R1 Sentinel Bore	O-R1-005	387929.8154	6437072.721	50
R1 Sentinel Bore	O-R1-006	387929.8154	6437018.394	50
R1 Sentinel Bore	O-R1-007	387928.1937	6436969.742	50
R1 Sentinel Bore	O-R1-008	387929.0045	6436918.658	50
R1 Sentinel Bore	O-R1-009	388034.4163	6436940.551	50
R1 Sentinel Bore	O-R1-010	388035.2272	6437046.774	50
R1 Sentinel Bore	O-R1-011	388035.2272	6437159.483	50
R1 Sentinel Bore	O-R1-012	388033.6055	6437291.653	50
R2 Sentinel Bore	O-R2-001S	387821.8003	6436918.591	50
R2 Sentinel Bore	O-R2-001D	387821.8003	6436918.591	50
R2 Sentinel Bore	O-R2-002S	387821.027	6436971.175	50
R2 Sentinel Bore	O-R2-002D	387821.027	6436971.175	50
R2 Sentinel Bore	O-R2-003S	387822.5736	6437020.666	50
R2 Sentinel Bore	O-R2-003D	387822.5736	6437020.666	50
R2 Sentinel Bore	O-R2-004S	387823.3469	6437072.477	50
R2 Sentinel Bore	O-R2-004D	387823.3469	6437072.477	50
R2 Sentinel Bore	O-R2-005S	387822.5736	6437125.834	50
R2 Sentinel Bore	O-R2-005D	387822.5736	6437125.834	50
R2 Sentinel Bore	O-R2-006S	387822.5736	6437211.67	50
R2 Sentinel Bore	O-R2-006D	387822.5736	6437211.67	50
R2 Sentinel Bore	O-R2-007S	387824.1202	6437261.161	50
R2 Sentinel Bore	O-R2-007D	387824.1202	6437261.161	50
R2 Sentinel Bore	O-R2-008S	387869.7484	6437379.606	50
R2 Sentinel Bore	O-R2-008D	387869.7484	6437379.606	50
R3 Delineation Bores (western boundary O&P)	O-R3-001S	387460.8342	6436902.593	50

Purpose	Bore ID	Easting MGA94 (m)	Northing MGA94 (m)	Nominal PVC Diameter (mm)
R3 Delineation Bores (western boundary O&P)	O-R3-001D	387460.8342	6436902.593	50
R3 Delineation Bores (western boundary O&P)	O-R3-002S	387457.0333	6437067.298	50
R3 Delineation Bores (western boundary O&P)	O-R3-002D	387457.0333	6437067.298	50
R3 Delineation Bores (western boundary O&P)	O-R3-003S	387440.2904	6437233.164	50
R3 Delineation Bores (western boundary O&P)	O-R3-003D	387440.2904	6437233.164	50
R3 Delineation Bores (western boundary O&P)	O-R3-004S	387453.2324	6437396.71	50
R3 Delineation Bores (western boundary O&P)	O-R3-004D	387453.2324	6437396.71	50
R3 Delineation Bores (western boundary O&P)	O-R3-005S	387454.4993	6437638.701	50
R3 Delineation Bores (western boundary O&P)	O-R3-005D	387454.4993	6437638.701	50
Long Swamp Delineation Bore	LSD- A	387037.0586	6437195.161	50
Long Swamp Delineation Bore	LSD-B	387112.4685	6437029.745	50
Long Swamp Delineation Bore	LSD-C	387213.0152	6436922.712	50
Long Swamp Delineation Bore	N-019D	387276.14	6436758.5	50
Long Swamp Delineation Bore	N-019S	387276.46	6436760.6	50
Peron Quarry Delineation Bore	TPD-A	387408.4323	6437883.03	50
Peron Quarry Delineation Bore	TPD-B	387244.444	6437884.586	50
Peron Quarry Delineation Bore	TPD-C	387080.4557	6437883.03	50

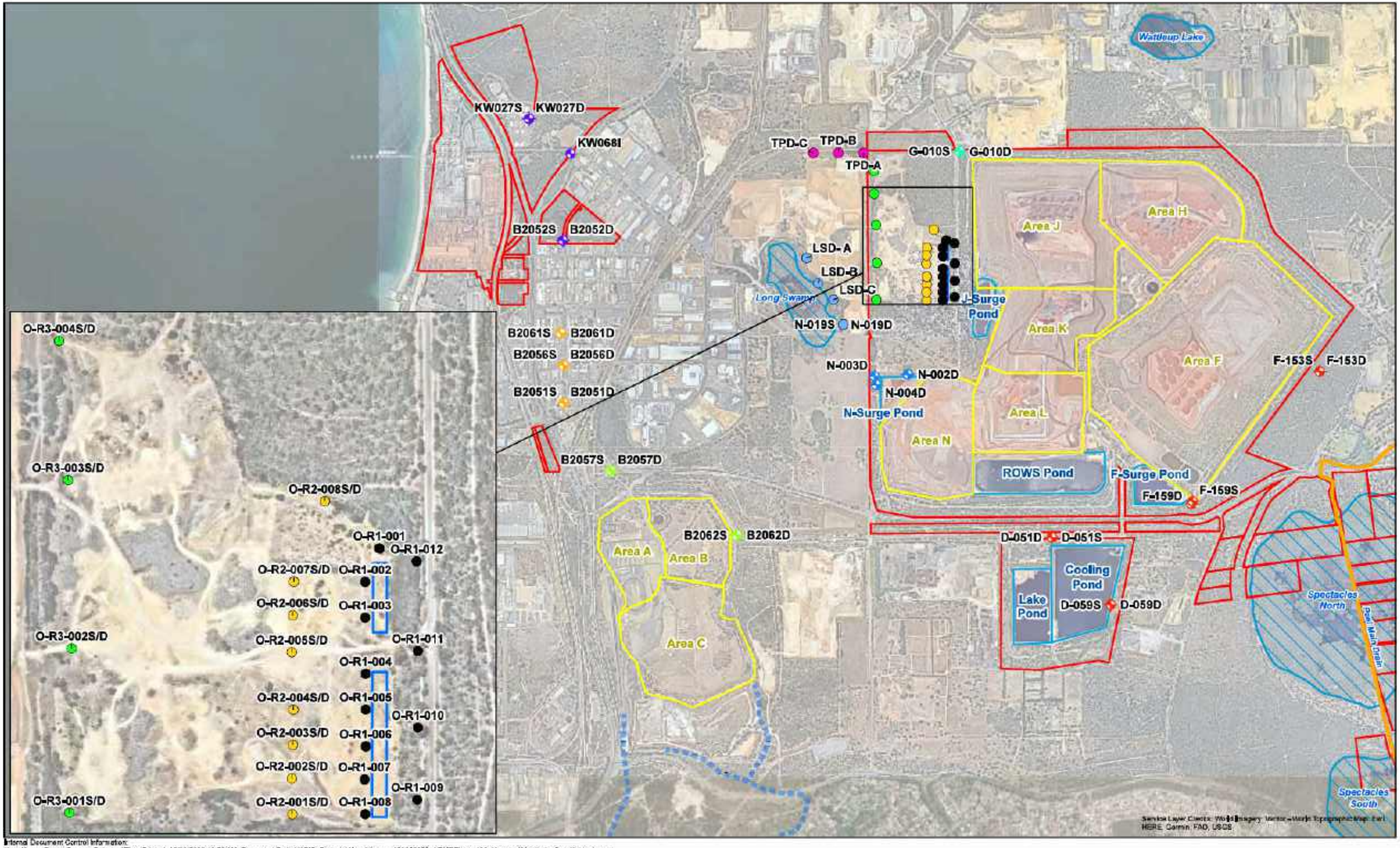
Table Notes:
mbtoc – metres below top of casing
(s) – shallow screened bore
(d) – deep screened bore

Table 3-4 Existing Monitoring Bores to be Incorporated into the Monitoring Bore Network

Purpose	Bore ID	Easting MGA94 (m)	Northing MGA94 (m)	Top of Steel Casing/ Reference Point (m AHD)	Nominal PVC Diameter (mm)	Depth to Top of Screen (m btoc)	Depth to Bottom of Screen (m btoc)
Other Unknown Contaminated Sites Delineation Bores	B2051D	385446.33	6436246.4	21.45	50	31	46.09
Other Unknown Contaminated Sites Delineation Bores	B2051S	385446.33	6436246.4	21.45	50	21.1	28
Other Unknown Contaminated Sites Delineation Bores	B2056D	385445.18	6436491.1	18.65	50	31.2	42.2
Other Unknown Contaminated Sites Delineation Bores	B2056S	385445.18	6436491.1	18.65	50	16.4	26.9
Other Unknown Contaminated Sites Delineation Bores	B2061D	385427.6	6436705.2	15.00	50	29.2	39.7
Other Unknown Contaminated Sites Delineation Bores	B2061S	385425.28	6436705.3	15.18	50	14.5	27.2
Refinery Plume Delineation Bore	B2052D	385441.31	6437309.7	16.365	50	29.7	41.3
Refinery Plume Delineation Bore	B2052S	385441.31	6437309.7	16.365	50	15.6	25.6
Refinery Plume Delineation Bore	KW027D	385219.92	6438106.5	20.73	50	31.6	46.6
Refinery Plume Delineation Bore	KW027S	385219.92	6438106.5	20.73	50	19.6	29.5
Refinery Plume Delineation Bore	KW068S	385493.2	643880.04	9.51	50	7.77	13.77
Refinery Plume Delineation Bore	KW068I	385491.97	6437878.2	9.45	50	17.57	23.57
RSA ABC Delineation Bore	B2057D	385755.99	6435802.3	12.99	50	25.7	36.4
RSA ABC Delineation Bore	B2057S	385755.99	6435802.3	12.99	50	11.6	21.3
RSA ABC Delineation Bore	B2062D	386580.45	6435381.4	21.72	50	32.95	41.95
RSA ABC Delineation Bore	B2062S	386580	6435379.5	21.72	50	21.5	31
Upgradient Baseline	D-059D	388889	6434776	34.73	50	42.84	54
Upgradient Baseline	D-059S	388888	6434774	34.75	50	30.87	40
Upgradient Baseline	F-153D	390395.18	6436452.6	27.57	50	38.6	46.1
Upgradient Baseline	F-153S	390395.18	6436452.6	27.57	50	12	34
Upgradient Baseline	F-159D	389555.05	6435585.8	45.565	50	55.5	65.5
Upgradient Baseline	F-159S	389564.33	6435603.1	45.82	50	37.5	53.5
Upgradient Baseline	D-051D	388502	6435217	19.44	50	30	41
Upgradient Baseline	D-051S	388504	6435217	19.43	50	17	28.2
Northern Site Boundary Delineation Bore	G-010D	388039.3	6437891.1	24.96	50	36	46
Northern Site Boundary Delineation Bore	G-010S	388038.56	6437894.4	24.94	50	23.4	33.5

Purpose	Bore ID	Easting MGA94 (m)	Northing MGA94 (m)	Top of Steel Casing/ Reference Point (m AHD)	Nominal PVC Diameter (mm)	Depth to Top of Screen (m btoc)	Depth to Bottom of Screen (m btoc)
Southern Site Delineation Bore	N-002D	387701.06	6436432.9	15.751	50	27.776	36.776
Southern Site Delineation Bore	N-002S	387699.12	6436433.2	15.843	50	15.251	24.551
Southern Site Delineation Bore	N-003D	387481.5	6436420.5	11.042	50	20.825	29.725
Southern Site Delineation Bore	N-003S	387481.5	6436420.5	11.77	50	10.2	18.6
Southern Site Delineation Bore	N-004D	387491.77	6436365	13.742	50	24.795	35.095
Southern Site Delineation Bore	N-004S	387491.77	6436365	13.77	50	13.232	22.332

Table Notes:
mbtoc – metres below top of casing
S – shallow screened bore
D – deep screened bore



Internal Document Control Information:
User Name: Danny.Barnes, Date and Time Printed: 10/02/2025 10:56 AM, Document Path: Y:\GIS_Projects\Alcoa\Kwinana\20250623_ARMPFigures\03_Mapping\MonitoringBoreNetwork.aprx

Proposed Groundwater Monitoring Bore Network

0 0.25 0.5 1 1.5 2 km

[Page Size: A3]

LEGEND

- Peel Main Drain
- Waterways
- Undefined Drainage Line
- Residue Storage Areas
- Storage Ponds
- Alcoa Property Boundary
- Wetlands
- Proposed Diffusion Trench

Existing Monitoring Bores
- Refinery Plume Delineation Bores
- Southern Site Delineation Bores
- Northern Site Delineation Bores
- RSA ABC Plume Delineation Bores
- Other Unknown Contaminated Sites Delineation Bores
- Upgradient Baseline

Additional Monitoring Bores
- R1 Sentinel Bore
- R2 Sentinel Bore
- R3 Delineation Bores (western boundary of D&P area)
- Long Swamp Delineation Bores
- Peron Quarry Delineation Bores

Monitoring and Management Plan

EHS Support

Perth

Figure 3-2

CREATED BY:	D. Barnes
APPROVED BY:	C. Smith
PROJECT REF. NO:	PTY.06199
MAP PROJECTION:	Transverse Mercator
GRID/DATUM:	GDA2020 MGA Zone 50
SCALE:	1:22,239
AERIAL IMAGE SOURCE:	ESRI Basemap

N

3.4 Rationale for Monitoring Parameters, Frequency, and Methods

As noted above, the monitoring program has been designed to:

- Assess the effectiveness of the infiltration trenches in controlling the flux of constituents.
- Support our understanding of downgradient advective and dispersive mixing and attenuation reactions.
- Assess the effectiveness of preventing existing third-party plumes from spreading laterally and/or vertically.
- Assess migration pathways and potential impacts to third-party groundwater users and Long Swamp via groundwater discharge.
- Evaluate potential mobilising of existing groundwater plumes beneath the Refinery and discharge to Cockburn Sound. As noted in **Section 4**, this will also be supported by sampling the foreshore pore water and marine environment if required.

The monitoring strategy for the protection of receptors and assessment of potential risks associated with infiltration is presented in **Table 3-1**. The monitoring and sampling program includes manual gauging, high-frequency recording of groundwater levels and EC using pressure transducers, sampling select sentinel monitoring bores for indicator parameters and sampling the entire monitoring network for the primary water quality parameter suite to support assessment and decision-making activities. A summary of this program is presented in the sections below.

3.4.1 Rationale for Groundwater Level Recording

High-frequency groundwater levels will be recorded using telemetered automated pressure transducers at selected R1 Sentinel Bores, R2 Sentinel Bores, and R3 Delineation Bores as an indicator or early warning of non-optimal groundwater mounding. Manual gauging of groundwater levels will be undertaken monthly at select R1 Sentinel Bores and R2 Sentinel Bores, and quarterly at R3 Delineation Bores and other Delineation Bores proximal to receptors and areas of interest (i.e., third-party groundwater plumes). Increased frequency of manual gauging may be employed where a non-optimal condition is observed.

3.4.2 Rationale for Analytical Suite

A laboratory testing program has been developed to provide quantitative data to:

- Ensure that the permeate is of suitable quality for infiltration.
- Develop a baseline understanding of groundwater conditions in the Tamala Limestone, which can then be used to complement the background Tamala Limestone UPL trigger levels, to identify a non-optimal condition or a change in conditions that could result in a potential risk to receptors.
- Develop a baseline understanding of surface water conditions in Long Swamp to assist with validating groundwater discharge mechanisms.
- Provide early warnings of potential risks downgradient of the infiltration trenches.
- Evaluate the potential risks to receptors and the environment.
- Evaluate whether infiltration will cause the migration of existing third-party groundwater plumes.

The constituents of relevance for laboratory analysis during the activity of infiltration are based on the framework presented in **Section 4**. Rationales for the proposed analytical suites are provided in **Table 3-5**.

Table 3-5 Proposed Analytical Suites

Purpose of Analysis	Analytes	Comment/Purpose
Commissioning Phase Permeate and Condensate	**Comprehensive Commissioning Phase Analytical Suite** • General parameters: pH, TDS, EC, TSS, hardness • Radionuclides: Gross alpha and gross beta • Cations: Ca, Mg, Na, K • Anions: Cl, SO_4, alkalinity, (total, carbonate and bicarbonate) • Major elements/metals: Al, Fe, Mn, Si, Ti, Cyanide, Fluoride • Trace elements/metals: Ag, As, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Ga, Gd, Ge, Hf, Hg, Ho, In, La, Li, Lu, Mo, Nb, Nd, Ni, Pr, Pb, Rb, Re, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tm, U, V, W, Y, Yb, Zn, Zr • Nutrients: Ammonia, Total Nitrogen, Nitrite, Nitrate, TKN, Total Phosphorus, Phosphate • Sulfur species: Sulfur, Carbon disulfide, Sulphate, Sulphide, Sulphite, Thiosulphate • Carbon species: Total Carbon, Total Inorganic Carbon, Total Organic Carbon • PFAS: Standard 28 analytes • Pesticides: Organophosphorus pesticides, organochlorine pesticides, phenols, and nitrophenols • Infiltration suite: Methane, NDMA, Boron, Iron (Fe^{2+} and Fe^{3+})	Prior to infiltration, Alcoa will undertake a two-week trial to demonstrate that the water quality specification is being achieved. No water will be infiltrated during this period.
Baseline evaluation of groundwater conditions prior to the commencement of infiltration	**Comprehensive Baseline Analytical Suite*** • pH, EC, TDS, hardness • Anions: Cl, SO_4, fluoride, alkalinity, (total, carbonate and bicarbonate) • Cations: Ca, Mg, Na, K • Nutrients (ammonia, phosphate, phosphorus, nitrate, nitrite, ammonia, total N). • Metals Screen (Ag, Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Ga, Li, Pb, Mn, Hg, Mo, Ni, Sb, Se, Sn, Sr, Th, Ti, U, V, Zn). • Other: silica, cyanide, ferrous iron • PFAS: Standard 12 analytes	Analytical results will allow for statistical analysis and the derivation of appropriate baseline statistics to compliment the Tamala Limestone background UPLs that have been adopted as trigger criteria.
Baseline evaluation of surface water conditions in Long Swamp prior to the commencement of infiltration	**Comprehensive Baseline Analytical Suite*** • pH, EC, TDS, hardness • Anions: Cl, SO_4, fluoride, alkalinity, (total, carbonate and bicarbonate) • Cations: Ca, Mg, Na, K • Nutrients (ammonia, phosphate, phosphorus, nitrate, nitrite, ammonia, total N). • Metals Screen (Ag, Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Ga, Li, Pb, Mn, Hg, Mo, Ni, Sb, Se, Sn, Sr, Th, Ti, U, V, Zn). • Other: silica, cyanide, ferrous iron • PFAS: Standard 12 analytes	Analytical results will allow for statistical analysis and the derivation of appropriate baseline statistics to be used to assist with validating groundwater discharge mechanisms.

Purpose of Analysis	Analytes	Comment/Purpose
Operational Phase Infiltration	**Primary Water Quality Suite*** • General parameters: pH, TDS, cations (Ca, K, Mg, Na) and anions (Cl, NO_3, SO_4, fluoride and alkalinity). • Metals: Al, As, B, Ga, Mo, Ni, Se, Sn, V • Other: hardness	This laboratory suite provides an assessment of key analytes based on the framework presented in **Section 2.6.** The suite is robust with respect to chemical substances likely to be associated with the activity. As noted above weekly samples of the permeate as it is discharged to the infiltration trenches will be collected. A 30-day flow weighted average concentration of the primary water quality suite will be determined and assessed against the compliance criteria.
Early Warning (R2 Sentinel Bores)	• Sodium, EC and pH	Analytical results will indicate whether there is a potential for impacts to occur downgradient of the infiltration trenches. There is a notable difference between the sodium and EC of the permeate when compared with baseline Tamala Limestone groundwater quality. The results provide an opportunity to mitigate potential impacts. Discrete sampling events of the primary water quality parameter suite will be undertaken to evaluate impacts to receptors where sodium and EC show a non-optimal condition
Risk Assessment and Geochemical Mixing Assessment (R2 Sentinel Bores, R3 Delineation Bores, other Delineation Bores proximal to receptors and areas of interest)	**Primary Water Quality Suite*** • General parameters: pH, TDS, cations (Ca, K, Mg, Na) and anions ((Cl, NO_3, SO_4, fluoride and alkalinity). • Metals: Al, As, B, Ga, Mo, Ni, Se, Sn, V • Other: hardness	The primary water quality parameter suite provides an assessment of key analytes and to evaluate potential impacts to downgradient receptors. The suite is robust with respect to chemical substances likely to be associated with the activity.

Table Notes:
* Field parameters to be collected prior to sampling and include EC, pH, temperature

For adaptive management to be effective, a combination of real-time and analytical data needs to be utilised. Real-time/field data (such as telemetered pressure transducers) provides the advantage of there being no delays in receipt of the data and, as a result, modifications to the infiltration operations can be conducted in real time. Analytical data can take up to 14 days to be received and reviewed (due to Quality Assurance/Quality Control [QA/QC] checks on the data set) but provides direct comparison to trigger levels.

3.4.3 Rationale for Sampling Frequency

Table 3-6 presents a summary of the proposed sampling frequency for specific analytical suites across the different types of monitoring bores. The monitoring frequencies chosen are suitable to identify changes in groundwater conditions that may impact downgradient receptors and are informed by the calculated groundwater seepage velocities between the infiltration location and the monitoring bores.

Table 3-6 Sampling Frequency Summary

Purpose of Analysis	Analytical Suite	Sampling Frequency
Commissioning Phase Permeate and Condensate	Comprehensive Commissioning Phase Analytical Suite	Prior to infiltration, Alcoa will undertake a two-week trial to demonstrate the plant is operating as designed and the treated water meets the compliance criteria. The treated water will be continuously monitored for EC and pH, and samples will be taken at a minimum of once a day for a period of two weeks and analysed by a NATA-accredited laboratory.
Commissioning Phase Baseline Assessment: Groundwater and Surface Water	Comprehensive Baseline Analytical Suite	Sampling of the surface water at Long Swamp at up to 3 discrete locations monthly over a period of 6 months. Collection of a minimum of four rounds of sampling across the R2 Sentinel Bores, R3 Delineation Bores, proximal Delineation Bores, and nominated existing monitoring bore network for a comprehensive analytical suite to establish baseline conditions. Collection of 4-6 months of groundwater levels across the R1/R2 sentinel bores, Delineation bores, and existing monitoring bores to establish natural variation.
Operational Phase Infiltration	pH and EC Primary Water Quality Suite	Continuous monitoring of pH and EC of the treated water at the Water Treatment Plant will be undertaken. Weekly samples of the permeate as it is discharged to the infiltration trenches will be collected. A 30-day flow weighted average concentration of the primary water quality suite will be determined and assessed against the compliance criteria. The monthly flow weighted averages will be calculated using the individual weekly sample results (a minimum of 4 in a month). The concentration of each sampling event will then be multiplied by the increment of flow for the sampling period (sum of the flow from the preceding sampling event to this sampling event divided by the total flow for the monthly period) and these increments with be summed together to provide the flow weighted value.
Operating Phase R2 Sentinel Bores	Sodium, EC and pH	Monthly sampling of selected R2 Sentinel Bores for sodium, EC and pH only. It is noted that pressure transducers with EC logging capabilities will also be installed at selected R2 Sentinel Bores. These bores will not be sampled.
Operating Phase R3 Delineation Bores Other Delineation Bores proximal to receptors or areas of interest	Primary Water Quality Suite	Three-monthly sampling of R3 Delineation Bores Annual sampling of other Delineation Bores. In the instance that a trigger level or a non-optimal condition is observed in R2 Sentinel Bores and/or R3 Delineation Bores, sampling frequency may be increased at the Other Delineation Bores.
Operating Phase Refinery groundwater monitoring bores, foreshore porewater and marine environment	Primary Water Quality Suite	Sampling to be undertaken as required when non-optimal conditions are observed at Refinery Delineation Bores and there are indications of deleterious changes in groundwater conditions downgradient.

Table Notes:
EC – electrical conductivity
NATA – National Association of Testing Authorities

Table 3-7 presents the proposed groundwater level monitoring requirements across the monitoring network, and **Table 3-8** presents the proposed water quality sampling requirements across the monitoring network.

Table 3-7 Groundwater Monitoring Program – Groundwater Levels

Purpose	Bore ID	New or Existing	Manual gauging Monthly	Manual gauging Every three months	Pressure Transducers 1 hour frequency of recording
R1 Sentinel Bore	O-R1-001	New	-	-	✓
R1 Sentinel Bore	O-R1-002	New	✓	-	-
R1 Sentinel Bore	O-R1-003	New	-	-	✓
R1 Sentinel Bore	O-R1-004	New	-	-	✓
R1 Sentinel Bore	O-R1-005	New	✓	-	-
R1 Sentinel Bore	O-R1-006	New	-	-	✓
R1 Sentinel Bore	O-R1-007	New	✓	-	-
R1 Sentinel Bore	O-R1-008	New	-	-	✓
R1 Sentinel Bore	O-R1-009	New	-	-	✓
R1 Sentinel Bore	O-R1-010	New	✓	-	-
R1 Sentinel Bore	O-R1-011	New	-	-	✓
R1 Sentinel Bore	O-R1-012	New	✓	-	-
R2 Sentinel Bore	O-R2-001S	New	✓	-	-
R2 Sentinel Bore	O-R2-001D	New	✓	-	-
R2 Sentinel Bore	O-R2-002S	New	-	-	✓#
R2 Sentinel Bore	O-R2-002D	New	✓	-	-
R2 Sentinel Bore	O-R2-003S	New	✓	-	-
R2 Sentinel Bore	O-R2-003D	New	✓	-	-
R2 Sentinel Bore	O-R2-004S	New	-	-	✓#
R2 Sentinel Bore	O-R2-004D	New	✓	-	-
R2 Sentinel Bore	O-R2-005S	New	✓	-	-
R2 Sentinel Bore	O-R2-005D	New	✓	-	-
R2 Sentinel Bore	O-R2-006S	New	-	-	✓#
R2 Sentinel Bore	O-R2-006D	New	✓	-	-
R2 Sentinel Bore	O-R2-007S	New	-	-	✓#
R2 Sentinel Bore	O-R2-007D	New	-	-	✓#
R2 Sentinel Bore	O-R2-008S	New	✓	-	-
R2 Sentinel Bore	O-R2-008D	New	✓	-	-
R2 Sentinel Bore	O-R2-009S	New	✓	-	-
R2 Sentinel Bore	O-R2-009D	New	✓	-	-
R3 Delineation Bores (western boundary O&P)	O-R3-001S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-001D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-002S	New	-	-	✓
R3 Delineation Bores (western boundary O&P)	O-R3-002D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-003S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-003D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-004S	New	-	-	✓
R3 Delineation Bores (western boundary O&P)	O-R3-004D	New	-	✓	-

Purpose	Bore ID	New or Existing	Manual gauging Monthly	Manual gauging Every three months	Pressure Transducers 1 hour frequency of recording
R3 Delineation Bores (western boundary O&P)	O-R3-005S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-005D	New	-	✓	-
Long Swamp Delineation Bore	LSD- A	New	-	✓	-
Long Swamp Delineation Bore	LSD-B	New	-	-	✓*
Long Swamp Delineation Bore	LSD-C	New	-	✓	-
Long Swamp Delineation Bore	N-019D	Existing	-	✓	-
Long Swamp Delineation Bore	N-019S	Existing	-	✓	✓
Peron Quarry Delineation Bore	TPD-A	New	-	✓	-
Peron Quarry Delineation Bore	TPD-B	New	-	✓	-
Peron Quarry Delineation Bore	TPD-C	New	-	✓	-
Other Unknown Contaminated Sites Delineation Bore	B2051D	Existing	-	✓	-
Other Unknown Contaminated Sites Delineation Bore	B2051S	Existing	-	✓	-
Other Unknown Contaminated Sites Delineation Bore	B2056S	Existing	-	✓	-
Other Unknown Contaminated Sites Delineation Bore	B2056D	Existing	-	✓	-
Other Unknown Contaminated Sites Delineation Bore	B2061D	Existing	-	✓	-
Other Unknown Contaminated Sites Delineation Bore	B2061S	Existing	-	✓	-
Refinery Plume Delineation Bore	B2052D	Existing	-	✓	-
Refinery Plume Delineation Bore	B2052S	Existing	-	✓	-
Refinery Plume Delineation Bore	KW027D	Existing	-	✓	-
Refinery Plume Delineation Bore	KW027S	Existing	-	✓	-
Refinery Plume Delineation Bore	KW068S	Existing	-	✓	-
Refinery Plume Delineation Bore	KW068I	Existing	-	✓	-
RSA ABC Plume Delineation Bore	B2057D	Existing	-	✓	-
RSA ABC Plume Delineation Bore	B2057S	Existing	-	✓	-
RSA ABC Plume Delineation Bore	B2062D	Existing	-	✓	-
RSA ABC Plume Delineation Bore	B2062S	Existing	-	✓	-
Upgradient Baseline	D-059D	Existing	-	✓	-
Upgradient Baseline	D-059S	Existing	-	✓	-
Upgradient Baseline	F-153D	Existing	-	✓	-
Upgradient Baseline	F-153S	Existing	-	✓	-
Upgradient Baseline	F-159D	Existing	-	✓	-
Upgradient Baseline	F-159S	Existing	-	✓	-
Upgradient Baseline	D-051D	Existing	-	✓	-
Upgradient Baseline	D-051S	Existing	-	✓	-
Northern Site Delineation Bore	G-010D	Existing	-	✓	-
Northern Site Delineation Bore	G-010S	Existing	-	✓	-
Southern Site Delineation Bore	N-002D	Existing	-	✓	-
Southern Site Delineation Bore	N-002S	Existing	-	✓	-
Southern Site Delineation Bore	N-003D	Existing	-	✓	-

Purpose	Bore ID	New or Existing	Manual gauging Monthly	Manual gauging Every three months	Pressure Transducers 1 hour frequency of recording
Southern Site Delineation Bore	N-003S	Existing	-	✓	-
Southern Site Delineation Bore	N-004D	Existing	-	✓	-
Southern Site Delineation Bore	N-003S	Existing	-	✓	-

Table Notes:
* Pressure transducer to be installed assuming site access granted and will be a replacement for N-019S
# Pressure transducers with EC logging

Table 3-8 Groundwater Monitoring Program – Water Quality

Purpose	Bore ID	New or Existing	Sodium, EC and pH Monthly sampling	Primary Water Quality Suite Three monthly sampling	Primary Water Quality Suite Annual Sampling
R1 Sentinel Bore	O-R1-001	New	-	-	-
R1 Sentinel Bore	O-R1-002	New	-	-	-
R1 Sentinel Bore	O-R1-003	New	-	-	-
R1 Sentinel Bore	O-R1-004	New	-	-	-
R1 Sentinel Bore	O-R1-005	New	-	-	-
R1 Sentinel Bore	O-R1-006	New	-	-	-
R1 Sentinel Bore	O-R1-007	New	-	-	-
R1 Sentinel Bore	O-R1-008	New	-	-	-
R1 Sentinel Bore	O-R1-009	New	-	-	-
R1 Sentinel Bore	O-R1-010	New	-	-	-
R1 Sentinel Bore	O-R1-011	New	-	-	-
R1 Sentinel Bore	O-R1-012	New	-	-	-
R2 Sentinel Bore	O-R2-001S	New	✓	-	-
R2 Sentinel Bore	O-R2-001D	New	✓	-	-
R2 Sentinel Bore	O-R2-002S	New	✓	-	-
R2 Sentinel Bore	O-R2-002D	New	✓	-	-
R2 Sentinel Bore	O-R2-003S	New	✓	-	-
R2 Sentinel Bore	O-R2-003D	New	✓	-	-
R2 Sentinel Bore	O-R2-004S	New	✓	-	-
R2 Sentinel Bore	O-R2-004D	New	✓	-	-
R2 Sentinel Bore	O-R2-005S	New	✓	-	-
R2 Sentinel Bore	O-R2-005D	New	✓	-	-
R2 Sentinel Bore	O-R2-006S	New	✓	-	-
R2 Sentinel Bore	O-R2-006D	New	✓	-	-
R2 Sentinel Bore	O-R2-007S	New	✓	-	-
R2 Sentinel Bore	O-R2-007D	New	✓	-	-
R2 Sentinel Bore	O-R2-008S	New	✓	-	-
R2 Sentinel Bore	O-R2-008D	New	✓	-	-
R2 Sentinel Bore	O-R2-009S	New	✓	-	-
R2 Sentinel Bore	O-R2-009D	New	✓	-	-
R3 Delineation Bores (western boundary O&P)	O-R3-001S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-001D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-002S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-002D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-003S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-003D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-004S	New	-	✓	-

Purpose	Bore ID	New or Existing	Sodium, EC and pH Monthly sampling	Primary Water Quality Suite Three monthly sampling	Primary Water Quality Suite Annual Sampling
R3 Delineation Bores (western boundary O&P)	O-R3-004D	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-005S	New	-	✓	-
R3 Delineation Bores (western boundary O&P)	O-R3-005D	New	-	✓	-
Long Swamp Delineation Bore	LSD- A	New	-	-	✓
Long Swamp Delineation Bore	LSD-B	New	-	-	✓
Long Swamp Delineation Bore	LSD-C	New	-	-	✓
Long Swamp Delineation Bore	N-019D	Existing	-	-	✓
Long Swamp Delineation Bore	N-019S	Existing	-	-	✓
Peron Quarry Delineation Bore	TPD-A	New	-	-	✓
Peron Quarry Delineation Bore	TPD-B	New	-	-	✓
Peron Quarry Delineation Bore	TPD-C	New	-	-	✓
Other Unknown Contaminated Sites Delineation Bore	B2051D	Existing	-	-	✓
Other Unknown Contaminated Sites Delineation Bore	B2051S	Existing	-	-	✓
Other Unknown Contaminated Sites Delineation Bore	B2056D	Existing	-	-	✓
Other Unknown Contaminated Sites Delineation Bore	B2056S	Existing	-	-	✓
Other Unknown Contaminated Sites Delineation Bore	B2061D	Existing	-	-	✓
Other Unknown Contaminated Sites Delineation Bore	B2061S	Existing	-	-	✓
Refinery Plume Delineation Bore	B2052D	Existing	-	-	✓
Refinery Plume Delineation Bore	B2052S	Existing	-	-	✓
Refinery Plume Delineation Bore	KW027D	Existing	-	-	✓
Refinery Plume Delineation Bore	KW027S	Existing	-	-	✓
Refinery Plume Delineation Bore	KW068S	Existing	-	-	✓
Refinery Plume Delineation Bore	KW068I	Existing	-	-	✓
RSA ABC Plume Delineation Bore	B2057D	Existing	-	-	✓
RSA ABC Plume Delineation Bore	B2057S	Existing	-	-	✓
RSA ABC Plume Delineation Bore	B2062D	Existing	-	-	✓
RSA ABC Plume Delineation Bore	B2062S	Existing	-	-	✓
Upgradient Baseline	D-059D	Existing	-	-	✓
Upgradient Baseline	D-059S	Existing	-	-	✓
Upgradient Baseline	F-153D	Existing	-	-	✓
Upgradient Baseline	F-153S	Existing	-	-	✓
Upgradient Baseline	F-159D	Existing	-	-	✓
Upgradient Baseline	F-159S	Existing	-	-	✓
Upgradient Baseline	D-051D	Existing	-	-	✓
Upgradient Baseline	D-051S	Existing	-	-	✓
Northern Site Delineation Bore	G-010D	Existing	-	-	✓
Northern Site Delineation Bore	G-010S	Existing	-	-	✓
Southern Site Delineation Bore	N-002D	Existing	-	-	✓

Purpose	Bore ID	New or Existing	Sodium, EC and pH Monthly sampling	Primary Water Quality Suite Three monthly sampling	Primary Water Quality Suite Annual Sampling
Southern Site Delineation Bore	N-002S	Existing	-	-	✓
Southern Site Delineation Bore	N-003D	Existing	-	-	✓
Southern Site Delineation Bore	N-003S	Existing	-	-	✓
Southern Site Delineation Bore	N-004D	Existing	-	-	✓
Southern Site Delineation Bore	N-004S	Existing	-	-	✓

Table Notes:
Primary Water Quality Parameter Analytical Suite – pH, TDS, cations and anions, Al, As, B, Ga, Mo, Ni, Se, Sn, V, nitrate, fluoride, hardness
EC – electrical conductivity

4 Adaptive Management Decision-Making Framework

On the basis of the objectives described above, the following decision-making framework and trigger levels (operating indicators and compliance trigger levels) have been developed to guide the optimisation of the infiltration activities and the management of impacts on the receiving environment. Consistent with these objectives, the decision-making framework provides a systematic assessment (step wise assessment framework) whereby efforts are made to optimise infiltration activities while ensuring no further degradation of downgradient groundwater quality and protection of existing beneficial uses.

The steps in the decision-making process are as follows, these include both operational indicators and compliance defined triggers as discussed in **Section 4.1**:

Optimisation and Efficiency

- Step 1: Optimise the performance of the infiltration trenches to maximise vertical flux and mixing, control downgradient flux in shallow portions of the aquifer, and ensure downgradient receptors are protected.
- Step 2: Ensure that infiltration is efficient and not causing large-scale vertical or lateral migration of existing groundwater plumes.

Protectiveness and Plume Stability

- Step 3: Ensure attenuation is occurring between R1/R2 Sentinel Bores and Receptor / Delineation Bores.
- Step 4: Ensure that groundwater quality in R3 Delineation Bores is consistent with baseline, consistent with permeate quality, or below adopted receptor Tier 1 screening criteria.
- Step 5: Ensure that groundwater quality in the receptor defined Delineation Bores (including R3 delineation bores) are protective of relevant receptor Tier 1 screening criteria or baseline.
- Step 6: Ensure that groundwater quality at existing third-party groundwater bores is consistent with baseline groundwater and/or applicable receptor Tier 1 screening criteria.
- Step 7: Ensure the groundwater plumes are stable and not mobilised.
- Step 8: Ensure surface water conditions are not adversely impacted (i.e., Long Swamp).

4.1 Trigger Levels

Trigger levels are designed to provide a method to identify either a non-optimal condition or a change in conditions that could result in a potential risk to receptors, and then to initiate a suitable response plan.

The Operational Indicators (**Table 4-1**) are designed to:

- Balance infiltration efficiency with visual amenity and reducing the risk of overflow and the creation of a water-dependent ecosystem (i.e., permanent pool of water).
- Evaluate mounding in the vicinity of the infiltration trench that relates to efficiency of infiltration and applicability of infiltration rate.
- Understanding mixing and geochemical reactions in the aquifer, in particular flux in the shallow or deep aquifer to validate the Hydrogeological Conceptual Site Model (HCSM).
- And provide an early warning for potential non-optimal or adverse conditions that may occur downgradient of the infiltration area (i.e., potential impacts to receptors).

Operational indicators are aspirational and do not have exact quantified trigger values with the exception of the stage height within the Infiltration Trench.

Compliance Triggers (**Table 4-2**) are defined to:

- Ensure trenches do not overflow.
- Inform if infiltrating water is potentially mobilising existing third-party groundwater plumes.
- Inform if groundwater quality due to infiltration is potentially impacting downgradient receptors.
- Inform what geochemical reactions may be occurring in the aquifer (i.e., such as dissolution).

The MMP establishes a means for managing potential groundwater risks and provides a mechanism whereby additional management measures or remedial actions can be implemented, in the event that site-specific trigger levels are exceeded. This recognises the fact that management of infiltration is adaptive and dynamic.

Table 4-1 (Operational Indicators) and **Table 4-2** (Compliance Triggers) below outline the operational indicators and compliance trigger levels to be adopted for the infiltration activity. These tables also present a systematic framework where proposed actions are implemented to address Operational Indicator early warnings and Compliance trigger level exceedances. The proposed actions will involve a thorough review of the data and a hydrogeological assessment of the potential causes for the exceedance of the trigger, so that recommendations for monitoring and management can be made on a case-by-case basis. Responses may be simple, such as moving or spreading the infiltration area inside the galleries, diverting off-spec water to the ROWS pond or addressing defects in water treatment systems. There may an increased frequency in sampling to further evaluate the reason for the trigger exceedance or confirm that the issue has been resolved after the implementation of other management actions. In some instances, responses may include the addition of monitoring bores for assessment (for example, the inclusion of monitoring bores on the periphery of existing groundwater plumes that may have expanded, or extra marine and foreshore sample locations where the Cockburn Sound criteria have been exceeded in **Refinery Delineation Bores**).

Infiltrated water and groundwater will be tested for the Primary Water Quality Suite (See **Sectio 2** for detail on how this was developed). Some analytes in the Primary Water Quality Suite have been included for general information and, although included in the testing regime, do not have triggers attached. For clarity, the primary water quality suite is reproduced in **Table 4-3** with trigger values for infiltrated water and groundwater. Note that the Tier 1 criteria used for groundwater quality triggers vary depending on the receptor being protected. The relevant criteria are specified in the trigger definition for each set of monitoring bores.

In accordance with US EPA Guidance, a resampling regime has been implemented for water quality results. This reduces the risk of actions being taken in response to false positives, whereby resampling will either confirm the exceedance or disclude it.

Table 4-1 Operational Indicators – Early Warning

Location	Indicator	Source	Actions	Purpose
Infiltrated Water	• Post-mineralisation pH and EC indicates calcium saturation	• Saturation level to be calculated from Commissioning Phase testing results.	• Reduce dosing rate at mineralisation plant and/or adjust pH	• Prevent precipitation of calcium and clogging of aquifer
	• Weekly testing indicates hardness does not meet the criteria to prevent dissolution	• Hardness criteria (or range) to be calculated from Commissioning Phase testing results using cation/anion data and geochemical models to define limits below calcite precipitation levels. • A minimum of 60 mg/L CaCO3eq will be assumed until Commissioning Phase testing outcomes.	• Adjust dosing rate at mineralisation plant • Retest to confirm hardness is within specified range	• Prevent dissolution of Tamala Limestone
Infiltration Trench	• Calcification evident in trench	• Periodic inspections. Key control is avoiding super/over saturation with calcium in the mineralisation plant	• Reduce dosing rate at mineralisation plant in 5 mg/L CaCO3eq increments • Manually break up calcified areas inside trench	• Avoid calcification in the infiltration trench
	• Water is not contained within infiltration gallery	• Manual visual inspections or use of cameras.	• Spread infiltration over a wider area or move to a different section of gallery.	• To ensure infiltration trenches do not overtop.
R1 Sentinel Bores with Pressure Transducers (O-R1-001, O-R1-003, O-R1-004, O-R1-006, O-R1-008, O-R1-009, O-R1-011)	• 30-day average groundwater level within 0.2m of surface in at least one monitoring bore	• Numerical groundwater model outputs (EHS Support, 2025a, **Appendix C**). • Groundwater levels	• Manual gauging to validate transducer data. • Review climatic and regional water level data to determine if the mounding is within the natural variability of groundwater level fluctuation. • Review hydraulic data from R2 Sentinel Bores and R3 Delineation Bores and confirm if groundwater mounding (if present) is within predicted bounds. • If required after the data review, within 30 days define appropriate response measures such as spreading infiltration water further across the trench length and/or reduce infiltration rates and/or bypass to ROWS Pond and/or modifications to lime dosing (if clogging is an issue)	• Early warning to prevent mounding above predicted levels at receptors. • Measure infiltration efficiency over time
R2 Sentinel Bores with Pressure Transducers (O-R2-002S, O-R2-004S, O-R2-006S, O-R2-007S, O-R2-007D)	• 30-day average groundwater level within 0.5m of surface in at least one monitoring bore with a pressure transducer.	• Numerical groundwater model (EHS Support, 2025a). • Groundwater levels	• Manual gauging of all R2 Sentinel Bores to validate pressure transducer data and provide a spatial understanding of groundwater levels. • Review climatic and regional water level data to determine if the mounding is within the natural variability of groundwater level fluctuation. • Review hydraulic data from R3 Delineation Bores and confirm if groundwater mounding (if present) is within predicted bounds. • If required after the data review, within 30 days define appropriate response measures such as spreading infiltration water further across the trench length and/or reduce infiltration rates and/or modifications to the infiltration trench depth and configuration.	• Early warning to prevent mounding above predicted levels at receptors. • Measure infiltration efficiency over time
R2 Sentinel Bores with Pressure Transducers (O-R2-002S, O-R2-004S, O-R2-006S, O-R2-007S, O-R2-007D)	• Comparison of EC changes in shallow and deep screened monitoring bores. No set action.	• Water quality monitoring compared to baseline (to be collected). • Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data following the installation of sentinel and delineation monitoring bores.	• Complete a review of water quality data from both the shallow and deep screened bores on a quarterly frequency to assess vertical migration and to inform changes or optimisation of the operation of the infiltration trenches. • Compare water quality to baseline and to infiltrated water quality on a quarterly basis and estimate the magnitude of mixing and dilution (or lateral attenuation) that is occurring and whether it is consistent with expectations (model results). • If water quality changes are evident in shallow screened monitoring bores and not consistent with expectations, constrain the infiltration area within galleries to maximise hydraulic head and encourage vertical migration of water (to the extent that this does not cause overtopping or mounding).	• To improve understanding of vertical migration • Characterise the magnitude of mixing and dilution
R2 Sentinel Bores O-R2-001S, O-R2-001D, O-R2-002S, O-R2-002D, O-R2-003S, O-R2-003D, O-R2-004S, O-R2-004D, O-R2-005S, O-R2-005D, O-R2-006S, O-R2-006D, O-R2-007S, O-R2-007D O-R2-008S, O-R2-008D)	• Comparison of changes in Na:EC ratio in shallow and deep screened monitoring bores. No set action level specified			

Table 4-2 Compliance Triggers

Location	Trigger	Source	Action	Purpose
Infiltrated Water	• EC of treated water after mineralisation exceeds 925 µS/cm.	• Proxa compliance quality for the Primary Water Quality Parameter suite (refer to **Section 2**)	• Treated water automatically directed to the ROWS pond and will not be infiltrated. • Investigate and resolve potential causes in the Water Treatment Plant(s). • Resume infiltration once EC is within the required specification.	• To demonstrate that water treatment is effective and to ensure that off-spec water is not infiltrated, protecting all receptors
	• Weekly sampling results exceed compliance criteria	• Proxa compliance quality for the Primary Water Quality Parameter suite (refer to **Table 4-3**)	• Resample to confirm water quality results • Forecast to determine when the 30-day flow-weighted average will exceed specification. • Notify regulator with forecast results (including sensitivity analysis) if water quality is not improved. • Investigate and resolve potential causes in the Water Treatment Plant(s). • Review internal testing from each Water Treatment Plant. If reason for exceedance can be isolated to a particular treatment plant, consider bypassing that plant to the ROWS Pond. • Resample after corrective actions taken to confirm water quality meets compliance criteria. • If water is still not within compliance criteria, stop infiltration prior to 30-day flow weighted average concentrations exceeding compliance criteria. • Investigate and resolve potential causes in Water Treatment Plant(s). • Resume infiltration once water quality meets specification.	• To demonstrate that water treatment is effective and to ensure that off-spec water is not infiltrated, protecting all receptors
	• 30-day flow weighted average concentrations of primary water quality parameters exceeds compliance criteria?	• Proxa compliance quality for the Primary Water Quality Parameter suite (refer to **Table 4-3**)	• Cease infiltration (for example, bypass to ROWS Pond) • Investigate and resolve potential causes in water treatment plant(s) • Resample after corrective actions taken to confirm water meets compliance criteria. • Resume infiltration once water quality meets specification.	• To demonstrate that water treatment is effective and to ensure that off-spec water is not infiltrated, protecting all receptors
R3 Delineation Bores with Pressure Transducers (O-R3-001S, O-R3-001D	• 30-day moving average groundwater level 0.5m above baseline in at least one monitoring bore • Interim trigger (applicable for first 12 months of operation). Baseline calculated using available monitoring data at the time infiltration commenced. • Proposed Future Trigger: Baseline revised over a longer time period. Time period to be decided based on review of water levels in R1 and R2 bores and climate data. Note that it will take over 12 months after commencement for any mounding to reach R3 bores.	• Monitoring data from bores with pressure transducers deployed. • Numerical groundwater model (EHS Support, 2025a, **Appendix C**)	• Manual gauging to validate pressure transducer data • Review of water levels in R1 and R2 Sentinel Bores and regional groundwater level data to determine if infiltration is the cause, or if water levels are within natural variability. • Increase frequency of manually measuring the standing groundwater levels in down-gradient delineation bores by receptors to monthly (note there are water level triggers for these bores below) • Move or spread infiltration within galleries to reduce mounding in monitoring bores with exceedance. • If required, reduce infiltration rate to reduce mounding in monitoring bores with exceedance. • Resume normal frequency of monitoring in down-gradient delineation bores once groundwater levels in R3 delineation bores are <0.5m above baseline. • If infiltration rate was slowed, incrementally increase rate once groundwater levels in R3 delineation bores are <0.5m above baseline.	• Early warning for mounding and associated flux increases higher than predicted at all downgradient receptors
	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and one of: ○ 95% ANZG ○ NPUG ○ Cockburn Sound Criteria.	• Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data following the installation of R3 Delineation Bores. • ANZG (2018) 95% species protection freshwater • DoH (2014) non-potable groundwater use • Cockburn Sound Criteria • Criteria are provided in **Table 4-3**	• Resample to validate results. • Identify potentially impacted down-gradient receptors based on Tier 1 criteria exceedances. • Evaluate attenuation between infiltration galleries and R3 Delineation Bores to predict concentrations once groundwater reaches receptor sites. • Review infiltration water quality and water quality in R1 and R2 bores to determine source of water quality change and whether infiltration is the cause. • Assess potential pathways to receptors based on whether exceedance is in shallow or deep screened R3 Delineation Bores (for example, an exceedance in deep bores is less likely to impact wetland receptors than an exceedence in shallow bores as wetlands interact with the top of the surficial aquifer). • Increase frequency of water quality sampling at relevant down-gradient receptors to quarterly. • If analysis indicates that attenuation is insufficient to protect receptors, implement actions to improve water quality. For example, move or spread infiltration within galleries or reduce the infiltration rate. • Resume normal frequency of monitoring once water quality in R3 Delineation Bores is with trigger level.	• Early warning to prevent water quality impacts at down-gradient receptors

Location	Trigger	Source	Action	Purpose
Long Swamp Delineation Bores	• Water level above 1.5mAHD at N-0195. N-0195 is the only existing monitoring bore adjacent to Long Swamp with long term groundwater level data. • Water level >0.3m above baseline in (LSD-A, LSD-B, LSD-C) • Interim baseline is the maximum recorded water level prior to commencing infiltration • Revised baseline is the maximum groundwater level calculated over a longer time period. Time period to be decided based on review of water levels in R1, R2 and R3 bores and climate data. • Note that it will take over 24 months after commencement for any mounding to reach Long Swamp.	• **Appendix E** shows the relevant trigger level and the long-term groundwater level trends. • Numerical groundwater model (EHS Support, 2025a, **Appendix C**) • Maximum groundwater mounding predicted by the model in the vicinity of the proposed delineation bores is 0.3 m (refer to model output in **Appendix C**).	• Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification) • Validate groundwater level data by manually gauging all Long Swamp Delineation Bores. • Review groundwater level data from surrounding groundwater monitoring bores and determine if mounding is within the natural variability of groundwater level fluctuations. • Measure the height of water in Long Swamp (if present) and collate regional groundwater and rainfall data • If surface water in Long Swamp is above 1.1m AHD, complete hydrogeological assessment to determine whether the water level is due to groundwater fluxes and if so evaluate potential risks to vegetation from mounding. This assessment may be supported by sampling Long Swamp and the Long Swamp Delineation Bores and subsequent analysis for the primary water quality suite. • Discuss findings with Regulator • If impacts to Long Swamp are not observed and/or not associated with groundwater infiltration, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates; or seeking approval for reinjection bores	• Prevention of inundation and waterlogging of vegetation in Long Swamp above the predicted 1.1m AHD level (unrelated to climatic events)
	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and 95% ANZG	• Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data following the installation of sentinel and delineation monitoring bores. • ANZG (2018) 95% species protection freshwater • Criteria are provided in **Table 4-3**	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Validate water quality results by resampling Long Swamp Delineation Bores. • Measure the height of water in Long Swamp and collate regional groundwater and rainfall data (if present) • Review groundwater hydraulic and climate data and water quality data from R2 and R3 Sentinel Bores to determine the source of water quality change. Complete assessment to determine axis of concentration change and potential causation. • Complete hydrogeological assessment to evaluate potential risks to Long Swamp and confirm groundwater surface water interaction mechanisms. This assessment may be supported by sampling Long Swamp and subsequent analysis for the primary water quality suite. • Discuss findings with Regulator • If impacts to Long Swamp are not observed and/or not associated with groundwater infiltration, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include, from least to most intensive, do nothing, spreading infiltration water across the entire trench length, reducing infiltration rates, complete an ecological risks assessment (the most intensive actions may take longer than the 60 day anticipated time frame).	• To assess whether groundwater concentrations have the potential to impact water quality within Long Swamp (unrelated to climatic events such as evapo-concentration)
Peron Quarry Third Party Plume Delineation Bores (TPD-A; TPD-B- TPD-C)	• Standing water level >0.4m above baseline. Baseline is the maximum water level recorded during baseline period (time period to be determined based on climate factors) • *Note that Alcoa is in talks with Synergy to use existing bores at Peron Quarry. If these existing bores are suitable, TPD A – C will not be installed. Suitable trigger levels based on bore location and baseline data will be determined prior to commencement of infiltration. • The methodology to calculate the trigger level is to add 0.4 m to the maximum groundwater level recorded during the baseline period (time period to be determined based on climate factors).	• Numerical groundwater model (EHS Support, 2025a, **Appendix C**) • Maximum groundwater mounding predicted by the model in the vicinity of the proposed delineation bores is 0.4 m (refer to model output in **Appendix C**).	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Manual gauging to Validate groundwater level data • Confirm that the groundwater level trigger has been exceeded. Determine if mounding is within the natural variability of groundwater level fluctuations. • Confirm if other anthropogenic activities may have influenced groundwater levels, such as third-party pumping or infiltration. • Complete hydrogeological assessment to evaluate potential risks to the Peron Quarry Plume. This assessment may include actions such as climatic analysis, third party groundwater operations review, groundwater gauging and sampling of other third party owned monitoring bores (cross gradient and downgradient of existing plume) and/or numerical modelling. • Discuss findings with Regulator. • If impacts to the Peron Quarry Third Party Plume are not observed, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates.	• Prevent mounding and associated flux above predicted levels at Peron Quarry

Location	Trigger	Source	Action	Purpose
Southern Site Delineation Bores (N-002S/D, N-003S/D, N-004S/D)	• Groundwater levels exceed trigger level • Trigger levels have been derived for the deeper screened bores as described below: ○ N-002D = 1.26 + 0.3 = 1.56 mAHD ○ N-003D = 1.26 + 0.3 = 1.56 mAHD ○ N-004D = 1.1 + 0.3 = 1.40 mAHD • There is no baseline data for shallow bores. The methodology to calculate the trigger level at the shallow bores is to add 0.3 m to the maximum groundwater level recorded during the baseline period (time period to be determined based on climate factors).	• **Appendix E** shows the relevant trigger level and the long-term groundwater level trends. • Numerical groundwater model (EHS Support, 2025a, **Appendix C**) • Maximum groundwater mounding predicted by the model in the vicinity of the delineation bores is 0.3 m (refer to model output in **Appendix C**).	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Validate groundwater level data by manually gauging all Southern Site Delineation Bores. • Confirm that the groundwater level trigger has been exceeded. Determine if mounding is within the natural variability of groundwater level fluctuations. • Confirm if other anthropogenic activities may have influenced groundwater levels, such as third-party pumping or infiltration (i.e. from Water Corporation). • Increase frequency of groundwater level monitoring to monthly in RSA ABC Delineation Bores and Other Unknown Contaminated Sites Delineation Bores, which are down-gradient. • Complete hydrogeological assessment to evaluate potential risks to downgradient receptors. This assessment may include actions such as climatic analysis, third party groundwater operations review, groundwater gauging and sampling of other Alcoa monitoring bores (cross gradient and downgradient) and/or analytical/numerical modelling. • Discuss findings with Regulator. • If impacts on receptors are not observed, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates. • Once groundwater levels fall below trigger levels, increase infiltration rate and resume normal frequency of monitoring.	• Confirm that mounding and associated flux changes are within predicted levels • To assess water quality impacts on other potential surface water receptors
	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and one of: ○ NPUG ○ Cockburn Sound Criteria	• Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data. • DoH (2014) non-potable groundwater use • Revised Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals – Technical Report (EHS Support, 2025d and **Appendix D**). • Criteria are provided in **Table 4-3**	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Confirm that primary water quality parameters exceed both the Background UPL and relevant Tier 1 screening criteria. • Validate water quality results by resampling Southern Site Delineation Bores. • Review groundwater hydraulic data and water quality data from R2 and R3 Sentinel Bores to determine the source of water quality change. Complete assessment to determine axis of concentration change and potential causation. • Identify potential downgradient receptors that may be at risk of impacts. • Complete hydrogeological assessment to evaluate potential risks to relevant receptors and confirm groundwater surface water interaction mechanisms. This assessment may be supported by sampling surface water receptors and subsequent analysis for the primary water quality suite. • Discuss findings with Regulator. • If impacts on receptors are not observed or predicted, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates and/or completing an ecological risks assessment.	• Prevention of water quality impacts at down-gradient receptors (Cockburn Sound and Groundwater Users) • To assess water quality impacts on other potential surface water receptors
Northern Site Boundary Delineation Bores (G-001S; G-001D)	• Standing water level >0.4m above baseline • Baseline is the maximum groundwater level recorded during the baseline period (time period to be determined based on climate factors).	• Numerical groundwater model (EHS Support, 2025a, **Appendix C**) • Maximum groundwater mounding predicted by the model in the vicinity of the delineation bores is ~0.4m (refer to model output in **Appendix C**).	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Validate groundwater level data by manually gauging all Northern Site Boundary Delineation Bores. • Confirm that the groundwater level trigger has been exceeded. Determine if mounding is within the natural variability of groundwater level fluctuations. • Confirm if other anthropogenic activities may have influenced groundwater levels, such as third-party pumping or infiltration. • Increase frequency of groundwater level monitoring at Peron Quarry Delineation Bores to monthly. • Implement action to lower groundwater level such as moving or spreading infiltration within galleries. • Once groundwater levels fall below trigger levels, resume normal frequency of monitoring.	• Confirm that mounding and associated flux changes are within predicted levels
	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and one of: ○ NPUG ○ Cockburn Sound Criteria	• Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data. • Revised Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals – Technical Report (EHS Support, 2025d and **Appendix D**). • DoH (2014) non-potable groundwater use • Criteria are provided in **Table 4-3**	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Confirm that primary water quality parameters exceed both the Background UPL and relevant Tier 1 screening criteria. • Validate water quality results by resampling the Northern Site Boundary Delineation Bores. • Review groundwater hydraulic data and water quality data from R2 and R3 Sentinel Bores to determine the source of water quality change. Complete assessment to determine axis of concentration change and potential causation. • Identify potential downgradient receptors that may be at risk of impacts. • Complete hydrogeological assessment to evaluate potential risks to relevant receptors • Discuss findings with Regulator. • If impacts on receptors are not observed or predicted, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates.	• Prevention of water quality impacts at down-gradient receptors (Cockburn Sound and Groundwater Users)

Location	Trigger	Source	Action	Purpose
Refinery Plume Delineation Bores (KW027S/D, KW068I, B2052S/D)	• Groundwater levels exceed: o 0.70 + 0.15 = 0.85 mAHD at KW027S o 0.73 + 0.15 = 0.88 mAHD at KW027D o 1.12 + 0.15 = 1.27 mAHD at KW068I o 0.92 + 0.15 = 1.07 mAHD at B2052S o 0.93 + 0.15 = 1.08 mAHD at B2052D • These trigger levels have been calculated by adding 0.15 m to the maximum groundwater elevation recorded since 2016.	• **Appendix E** shows the relevant trigger level and the long-term groundwater level trends. • Numerical groundwater model (EHS Support, 2025a, **Appendix C**) • Maximum groundwater mounding predicted by the model in the vicinity of the delineation bores is 0.15 m (refer to model output in **Appendix C**).	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Validate groundwater level data by manually gauging all Refinery Delineation Bores. • Confirm that the groundwater level trigger has been exceeded. Determine if mounding is within the natural variability of groundwater level fluctuations. • Confirm if other anthropogenic activities may have influenced groundwater levels, such as third-party infiltration and/or irrigation. • Gauge additional downgradient monitoring bores across the Refinery to assess gradient and flux changes. • Complete hydrogeological assessment to evaluate potential risks to Cockburn Sound from plume migration. This assessment may include actions such as climatic analysis, Alcoa groundwater operations review, groundwater gauging and sampling of other Alcoa monitoring bores (cross gradient and downgradient) and/or analytical/numerical modelling. • Discuss findings with Regulator. • If impacts on receptors are not observed, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates and/or increasing recovery of groundwater across the Refinery recovery bore network. • Once groundwater levels fall below trigger levels, increase infiltration rate (if reduced).	• Prevention of water quality impacts to Cockburn Sound due to plume migration
	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and Cockburn Sound Criteria.	• Revised Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals – Technical Report (EHS Support, 2025d and **Appendix D**). • Criteria are provided in **Table 4-3**	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** Confirm that primary water quality parameters exceed both the Background UPL and relevant Tier 1 screening criteria. • Validate water quality results by resampling the Refinery Plume Delineation Bores. • Review groundwater hydraulic data and water quality data from existing upgradient/cross-gradient and downgradient Alcoa monitoring bores. Complete assessment to determine axis of concentration change and potential causation. • Complete hydrogeological assessment to evaluate potential risks to Cockburn Sound and confirm groundwater surface water interaction mechanisms. Other data gaps to be addressed include: o Are the changes in water quality in the Refinery Delineation Bores associated with upgradient infiltration activities (i.e. mounding observed and/or groundwater geochemistry changes are consistent with the infiltrated water) o Are there indicators of deleterious changes in water quality within the downgradient Refinery and foreshore area. o Are there other indicators of increases of contaminant flux to the marine environment o This assessment may be supported by sampling other monitoring bores and the marine environment (i.e. sampling downgradient bores to determine if the plume has migrated). • Discuss findings with Regulator. • If impacts to Cockburn Sound are not observed or predicted, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates and/or increasing recovery of groundwater across the Refinery recovery bore network. • Resume normal operations once groundwater quality is within trigger criteria.	• Prevent water quality impacts to Cockburn Sound
RSA ABC Plume Delineation Bores (B2057S; B2057D; B2062S; B2062D)	• Groundwater level exceeds: o 1.02 + 0.15 = 1.17 mAHD at B2057S. o 1.03 + 0.15 = 1.18 mAHD at B2057D. o 1.28 + 0.15 = 1.43 mAHD at B2062S. o 1.14 + 0.15 = 1.29 mAHD at B2062D. • These trigger levels have been calculated by adding 0.15 m to the maximum groundwater elevation recorded since 2016.	• **Appendix E** shows the relevant trigger level and the long-term groundwater level trends. • Numerical groundwater model (EHS Support, 2025a, **Appendix C**) • Maximum groundwater mounding predicted by the model in the vicinity of the delineation bores is 0.15 m (refer to model output in **Appendix C**).	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Validate groundwater level data by manually gauging all RSA ABC Delineation Bores. • Confirm that the groundwater level trigger has been exceeded. Determine if mounding is within the natural variability of groundwater level fluctuations. • Confirm if other anthropogenic activities may have influenced groundwater levels, such as third-party pumping or infiltration. • Complete hydrogeological assessment to evaluate potential risks to downgradient receptors and determine whether flux changes will cause plume migration. This assessment may include actions such as climatic analysis, third party groundwater operations review, groundwater gauging and sampling of other Alcoa monitoring bores (cross gradient and downgradient) and/or analytical/numerical assessment. • Discuss findings with Regulator. • If impacts on receptors are not observed, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates and/or implementing changes in recovery bore operations at RSA ABC. • Once groundwater levels fall below trigger levels, resume normal operations.	• Prevent mounding and associated flux above predicted levels at RSA ABC that may cause to plume migration

Location	Trigger	Source	Action	Purpose
RSA ABC Plume Delineation Bores (B2057S; B2057D)	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and one of: o NPUG o Cockburn Sound Criteria.	• Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data following the installation of sentinel and delineation monitoring bores. • DoH (2014) non-potable groundwater use • Revised Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals – Technical Report (EHS Support, 2025d and **Appendix D**). • Criteria are provided in **Table 4-3**	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Confirm that primary water quality parameters exceed both the Background UPL and relevant Tier 1 screening criteria. • Validate water quality results by resampling the RSA ABC Plume Delineation Bores. • Identify potential downgradient receptors that may be at risk of impacts. • Review groundwater hydraulic data and water quality data from existing upgradient/cross-gradient and downgradient Alcoa monitoring bores. Complete assessment to determine axis of concentration change and potential causation. Assess hydraulic changes (i.e., mounding) and determine if flux change can potentially cause plume migration. • Complete hydrogeological assessment to evaluate potential risks to relevant receptors. This assessment may be supported by sampling additional monitoring bores for the primary water quality suite and increasing the frequency of sampling of the RSA ABC Plume Delineation Bores. • Discuss findings with Regulator • If impacts on receptors are not observed or predicted, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates and/or implementing changes in recovery bore operations at RSA ABC. • Resume normal operations once groundwater quality is within trigger criteria.	• To evaluate whether the existing plume may migrate and impact downgradient receptors
Other Unknown Contaminated Sites Delineation Bores (B2051S/D, B2055S/D, B2061S/D))	• Groundwater levels exceed: o 1.15 + 0.15 = 1.3 mAHD at B2051S o 1.13 + 0.15 = 1.28 mAHD at B2051D o 1.14 + 0.15 = 1.29 mAHD at B2056S o 1.07 + 0.15 = 1.22 mAHD at B2056D o 1.10 + 0.15 = 1.25 mAHD at B2061S o 1.05 + 0.15 = 1.20 mAHD at B2061D • These trigger levels have been calculated by adding 0.15 m to the maximum groundwater elevation recorded since 2016.	• **Appendix E** shows the relevant trigger level and the long-term groundwater level trends. • Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data • Maximum groundwater mounding predicted by the model in the vicinity of the delineation bores is 0.15 m (refer to model output in **Appendix C**).	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Validate groundwater level data by manually gauging all Other Unknown Contaminated Sites Delineation Bores. • Confirm that the groundwater level trigger has been exceeded. Determine if mounding is within the natural variability of groundwater level fluctuations. • Confirm if other anthropogenic activities may have influenced groundwater levels, such as third-party pumping or infiltration. • Complete hydrogeological assessment to evaluate potential risks to downgradient receptors and determine whether flux changes will cause plume migration. This assessment may include actions such as climatic analysis, third party groundwater operations review, groundwater gauging and sampling of other monitoring bores (cross gradient and downgradient) and/or analytical/numerical modelling. • Discuss findings with Regulator. • If impacts on receptors are not observed, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates. • Once groundwater levels fall below trigger levels, increase infiltration rate (if reduced).	• Prevent mounding and associated flux above predicted levels at Unknown contaminated sites may cause plume(s) to migrate (if present)
	• Primary water quality parameters exceed Background UPL (and Baseline UPL once available) and one of: o NPUG o Cockburn Sound Criteria.	• Proposed Background Environmental Monitoring Thresholds – Technical Memorandum (EHS, Support, 2025b, **Appendix A**) to be complimented with site determined baseline data. • DoH (2014) non-potable groundwater use • Revised Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals – Technical Report (EHS Support, 2025d and **Appendix D**). • Criteria are provided in **Table 4-3**	***Determine the potential for unacceptable risk by completion of the following systematic steps (within 60 days of notification)*** • Confirm that primary water quality parameters exceed both the Background UPL and relevant Tier 1 screening criteria. • Validate water quality results by resampling the Delineation Bores. • Identify potential downgradient receptors that may be at risk of impacts. • Review groundwater hydraulic data and water quality data from existing upgradient/cross-gradient and downgradient monitoring bores. Complete assessment to determine axis of concentration change and potential causation. Assess hydraulic changes (i.e., mounding) and determine if flux change can potentially cause plume migration. • Complete hydrogeological assessment to evaluate potential risks to relevant receptors. This assessment may be supported by sampling additional monitoring bores for the primary water quality suite and increasing the frequency of sampling of the Delineation Bores. • Discuss findings with Regulator • If impacts on receptors are not observed or predicted, continue at current infiltration rate. • If impacts are observed or predicted based on the assessment, implement actions following Regulator discussion. These actions may include spreading infiltration water across the entire trench length and/or reducing infiltration rates. • Resume normal operations once groundwater quality is within trigger criteria.	• To evaluate whether unknown contamination may migrate and impact downgradient receptors, such as existing groundwater users or Cockburn Sound

Table 4-3 Water Quality Triggers Summary

Primary Water Quality Suite Parameters		Units	Concentration in Infiltrated Water	Groundwater Triggers				
				Background UPL**	Tier 1 Screening Criteria			
					NPUG	Irrigation	95% ANZG	Cockburn Sound Criteria
General Parameters	pH	pH unit-	6.5 - 8.5	No trigger applied				
	TDS	mg/L	600	1,093	NC	NC	NC	NC
	Alkalinity	mg/L as $CaCO_3$	No trigger applied	No trigger applied				
	Hardness	mg/L as $CaCO_3$	*	No trigger applied				
Major Cations	Calcium	mg/L	*	350	NC	NC	NC	NC
	Magnesium	mg/L	5.0	40	NC	NC	NC	NC
	Sodium	mg/L	150	129	NC	NC	NC	NC
	Potassium	mg/L	No trigger applied	10.1	NC	NC	NC	NC
Major Anions	Chloride	mg/L	17.5	222	250	NC	NC	NC
	Fluoride	mg/L	0.5	0.41	15	2.0	1.7	NC
	Sulfate	mg/L	50.0	640	1000	NC	NC	NC
	Nitrate	mg/L	No trigger applied	47.4	500	NC	29	121.6
Metals	Aluminium	mg/L	0.15	0.04	0.2	20	0.055	0.086
	Arsenic	mg/L	0.01	0.03	0.1	2.0	0.013	0.017
	Boron	mg/L	0.9	0.13	40	NC	0.940	5.1
	Gallium	mg/L	0.005	0.002	NC	NC	NC	1.1
	Molybdenum	mg/L	0.09	0.007	0.5	0.05	0.034	6.2
	Nickel	mg/L	0.002	0.002	0.2	2.0	0.011	0.20
	Selenium	mg/L	0.01	0.004	0.1	0.05	0.011	0.01
	Tin	mg/L	0.002	0.001	NC	NC	NC	NC
	Vanadium	mg/L	0.01	0.009	NC	0.5	0.006	0.160

Table Notes

* Hardness and calcium criteria in infiltrated water to calculated from Commissioning Phase testing results using cation/anion data and geochemical models to define limits below calcite precipitation levels.

**Baseline UPL to be calculated from data collected prior to commencement of infiltration

4.2 Reporting Commitments

Following the implementation of the MMP, Alcoa will implement a routine reporting program that will comprise monthly review of monitoring results and results of the MMP, a quarterly status report, and a comprehensive Annual Compliance Report. The monthly tracking reports will focus on the rapid assessment of data and the provision of status and changes in accordance with the decision framework provided above. The quarterly reports will provide a more detailed assessment of data, ensuring the objectives (as described above) are met, the infiltration rate is optimised, and that impacts on the receiving environment are managed. Both the monthly and quarterly reports will highlight major operational concerns impacting on system performance, and the associated actions that Alcoa have implemented to ensure no further degradation of downgradient groundwater quality and that existing beneficial uses are protected. The quarterly reports will provide more detailed documentation on the analysis of data and demonstrate that actions were systematically implemented and appropriately assessed for any triggering event.

The Annual Compliance Report will consolidate the outcomes from the monthly, quarterly, and annual monitoring and sampling programs in accordance with the framework presented in the MMP.

Following the first 12 months of operation, the frequency of reporting commitments will be reviewed based on a risk management framework. This review will be in consultation with DWER.

4.2.1 Auto Reporting

To assist with the data review, and to provide information to Alcoa and key stakeholders as quickly and efficiently as possible, trigger levels will be applied to the continuous monitoring data. This will ensure that any key risks can be identified and informed decisions be made without delay.

4.3 Maintenance of System Operability and Performance

A core component of effective implementation of this MMP is implementation of a proactive maintenance program to ensure optimal performance of the infiltration trenches. The most frequent maintenance challenge with infiltration trenches is clogging. Core actions to be managed by Alcoa and a typical general schedule for infiltration trench maintenance is summarised in **Table 4-4**.

In addition to the operations and maintenance activities on the infiltration infrastructure, a separate operations and maintenance program has been developed for the water treatment plant.

Table 4-4 Maintenance Activities for Infiltration Trenches

Activity	Schedule
Replace gravel when clogged.	As needed
Maintain equipment spares to enable repairs and replacement to pumps and associated infrastructure in the field.	As needed
Clear inlet of debris, including sediment that could impact on inflows.	Monthly
Repair undercut and eroded areas at inflow structure.	Monthly
Inspect overflow pipes between infiltration trenches to ensure they are clear and functioning properly.	Monthly
Inspect integrity of R1 Sentinel Bores to ensure accurate monitoring of mounding.	Monthly
Complete inspections and, if needed, repairs on all monitoring wells.	Semi-annually
Inspect infrastructure and diversion structures for debris accumulation and structural integrity.	Semi-annually
Rehabilitate the trench and restore its design storage capacity.	Upon failure

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Appendix A Proposed Background Environmental Monitoring Thresholds – Technical Memorandum

Technical Memorandum

To: Alcoa of Australia (Limited)

From: EHS Support

Date: 19 November 2025

Re: Proposed Background Environmental Monitoring Thresholds

1 Introduction

Alcoa is evaluating the potential use of irrigation, infiltration, and direct injection into the Tamala Limestone aquifer as a means for management of treated groundwater, treated underdrain water and surface water from the residue storage areas. To support the approvals process, this document provides an assessment of background sampling data that was collected as part of a groundwater and surface water sampling program that was documented in the Sampling and Analysis Quality Plan (SAQP; EHS Support, 2024). This assessment documents the statistical approach and results of an assessment of background groundwater sampling data. The rationale for selection of background groundwater wells was documented in the aforementioned SAQP.

This technical memo includes an additional round of monitoring data not included in the previous draft assessment (EHS Support, 3 July 2025), as well as a more robust assessment of outliers. The inclusion of this additional data plus the removal of outliers has now resulted in calculated UPL values which do not significantly exceed the maximum observed concentrations. Further this technical memo also provides commentary that addresses the Interim Audit Advice on the draft assessment provided by Mr Jeremy Hogben of Senversa on the 25 July 2025.

A range of statistical methods can be used to define the upper bounds of background conditions within an aquifer. This assessment provides a statistical assessment of the data to define the upper bounds of natural background within the Tamala Limestone, Bassendean / Gnangara Sand and Ascot Formation. In combination with applicable regulatory criteria (aligned with the potential beneficial uses of each aquifer), this assessment will be used to define acceptable criteria for potential injection water and/or concentrations (trigger levels) in groundwater that may be indicative of potential impacts to groundwater; noting that technical assessments indicate that impacts to groundwater are unlikely.

This assessment will be used as a tool for the broader risk assessment described in the *Residue Storage Area ABC Irrigation Risk Assessment* (EHS Support, 2025a) and the *Aquifer Infiltration and Injection Technical Assessment and Risk Assessment* (EHS Support, 2025b) which are currently in development.

1.1 Road Map

The following outlines the road map for background water quality assessment and development of background environmental monitoring thresholds:

1. Identify monitoring bores that were representative of background, noting they are upgradient and cross gradient to the domains. This was completed as part of the SAQP (EHS Support, 2024) and based on location, bore integrity and surrounding activities.
2. Implement sampling program to collect initial data for assessment of background water quality and statistical analysis. Three initial sampling rounds were completed under the SAQP.
3. Evaluation of influences on water quality completed as part of the *Residue Storage Area ABC Irrigation Risk Assessment* (EHS Support, 2025a). Some examples include elevated nitrogen and phosphorus associated with historical agricultural activity in the area and elevated arsenic, manganese and silicon from natural geology of the area.
4. Qualitative assessment on outliers. Initial sampling data was reviewed, and qualitative outliers were removed based on elevated electrical conductivity which is not representative of background conditions.
5. Additional sampling completed to support quantitative outlier assessment. A fourth sampling round was completed in August 2025, and results were added to the background dataset to allow for comprehensive quantitative assessment and removal of outlier results.
6. Recalculation of UPLs using industry best practice methods in line with USEPA (2009) guidelines.
7. Evaluation of beneficial uses that are precluded based on background concentrations. This was completed as part of the *Residue Storage Area ABC Irrigation Risk Assessment* (EHS Support, 2025). Precluded beneficial uses include drinking water and terrestrial vegetation.
8. Background environmental thresholds are to be used to derive design criteria (for certain constituents) for infiltration / aquifer injection as outlined in the *DRAFT Aquifer Infiltration and Injection Technical Assessment and Risk Assessment* (EHS Support, 2025b).

2 Background Groundwater Bores

A systematic assessment of background groundwater well locations was undertaken as part of the SAQP (EHS Support, 2024) considering the following factors:

- The groundwater wells are hydraulically upgradient (or cross gradient) of Alcoa activities.
- The absence of contamination sources within the immediate vicinity of the groundwater well.
- Historical water quality data, where available, does not indicate impacts associated with Alcoa's activities.
- The background locations support the feasibility assessment for the infiltration/injection project.

Background groundwater wells are located across five specific focus areas and screened across three aquifers, as outlined in **Table 2-1** below and shown on **Figure 2-1**.

To support the development of background environmental thresholds, a total of 82 groundwater samples were collected from 21 monitoring wells. Each location was sampled four times, except for those outlined in **Table 2-2**. Round one samples were collected between October and November 2024, round two samples were collected between January and February 2025, round three samples were collected between April and May 2025 and round four samples were collected between July and August 2025. Sampling data from all four rounds has been included in this assessment.

Table 2-1 Background Wells by Aquifer

Bore ID	Screen from (mbTOC)	Screen to (mbTOC)	Area
Ascot Formation			
F-037D	61.1	64.6	Operating RSA
H-010D	62.3	69.8	Operating RSA
N-019D	15.3	27.5	Long Swamp
Bassendean / Gnangara Sand			
61410119	33	45	DWER
61419711	3	6	DWER
61419861	22	27	DWER
F-012B	34	61	Operating RSA
F-037S	33.9	58.1	Operating RSA
G-003	3	34.6	Spectacles Wetland
H-010S	35.8	57.8	Operating RSA
SP1-1D	3.6	7.6	Spectacles Wetland
Tamala Limestone			
61410078	35	41	DWER
B2052D	29.7	41.3	Refinery/Social Club Area
B2052S	15.6	25.6	Refinery/Social Club Area
G-005	1.7	25.1	Long Swamp
KW035D	19.6	31.6	Refinery/Social Club Area
KW035S	5.6	17.6	Refinery/Social Club Area
KW068D	26.62	32.62	Refinery/Social Club Area
KW068I	17.57	23.57	Refinery/Social Club Area
KW068S	7.77	13.77	Refinery/Social Club Area
N-019S	3.3	13.3	Long Swamp

Table 2-2 Summary of Groundwater Wells with Sample Anomalies

Well ID	Round 1	Round 2	Round 3	Round 4
G-005	Not sampled	Sampled	Sampled	Sampled
64140119	Sampled	Not sampled – well damaged	Sampled	Sampled
KW035D	Sampled	Sampled	Sampled	Sampled twice – initial sample adopted
KW035S	Sampled	Sampled	Sampled	Sampled twice – initial sample adopted

Groundwater sampling was conducted following methods detailed in the SAQP (EHS Support, 2024). Analytical suites were selected to provide a comprehensive dataset of key groundwater parameters and constituents of potential concern (COPCs) for the site. From this broader suite, constituents with at least two reported detections were selected to develop suitable environmental thresholds (upper prediction limits; UPLs).

It should be noted that the sampling locations within the Tamala Limestone are located within interior portions of the Alcoa property (not proximal to the coast), upgradient or cross gradient of areas of groundwater impacts and are therefore representative of freshwater in the Tamala Limestone. Major differences in groundwater chemistry (and associated minor ion concentrations) exist between the fresh and brackish (areas where saline intrusion has occurred) portions of the Tamala Limestone aquifer. No activities are proposed in the brackish portions of the aquifer and as a result background values for the saline portions of the aquifer have not been developed.

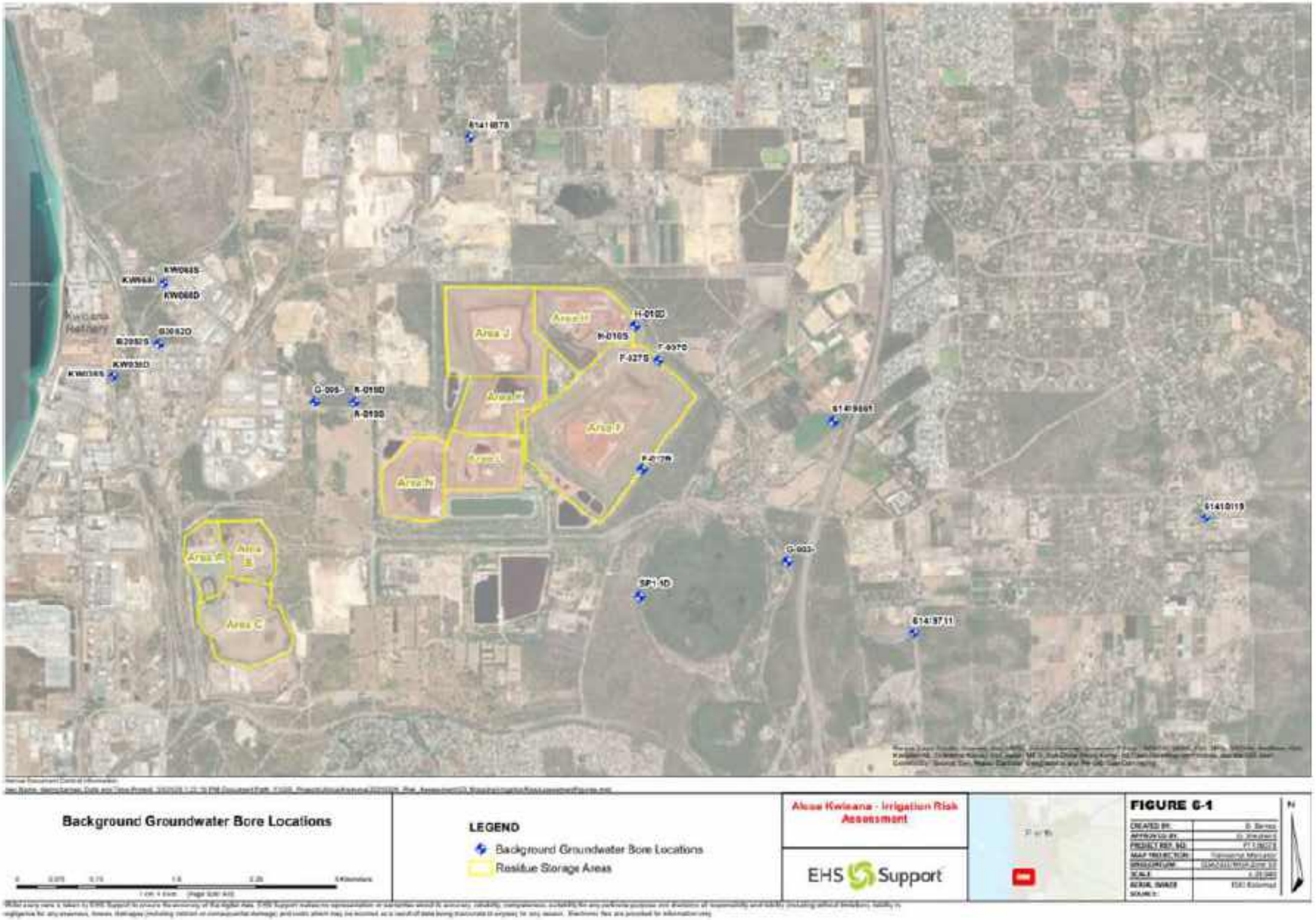


Figure 2-1 Background Groundwater Well Locations

3 Data Analysis Methods

Data were reviewed following methods described in *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance* (USEPA, 2009). In brief, the dataset was reviewed for outlying results, suitability for use in the development of environmental thresholds based on geochemical stability. Data were then reviewed to determine whether the statistical assumptions of tests were met. Data were then analysed based on methods appropriate given the distribution of the data and inter-well variation to calculate UPLs.

USEPA (2009) describes prediction limits as follows: "*...prediction limits belong to a class of methods known as statistical intervals. Statistical intervals represent concentration or measurement ranges computed from a sample that are designed to estimate one or more characteristics of the parent population. In groundwater monitoring, statistical intervals offer a convenient and statistically valid way to test for significant differences between background versus compliance point groundwater measurements.*"

Upper prediction limits (UPLs) are statistical estimates of the highest future concentration expected based on a given distribution of background data. UPLs were derived for each parameter. A 99% confidence, rather than a 95% confidence, is recommended for UPLs as it avoids frequent false-positive results impacting on the statistical tests (as per USEPA (2009) which is recognised by Australian environmental professionals as an appropriate guidance document in the absence of any formal Australian guidance). False negative results occur when a test fails to identify a true change from background; the risk of false negatives is assessed in **Appendix A** and aligned with guidance provided in USEPA (2009). False positive results occur when a test incorrectly identifies a normal concentration as different from background and are an inherent risk of statistical testing. Statistical testing with 99% confidence reduces the probability of false positives to 1% per test and balances the risk of false negative and false positive results.

The site-wide false positive rate (SWFPR) can be calculated as $1 - (1 - \alpha_{test})^{Nt}$ where *Nt* represents the total number of tests and α represents the significance level (confidence level of 99% is equivalent to α of 0.01; USEPA, 2009). This will be considered when selecting UPLs to use during review of future monitoring results.

Comprehensive details of the data analysis, statistical derivation methods and suitability assessment are provided in **Appendix A**.

4 Summary of Available Data

As described above, groundwater sampling was conducted in the Tamala Limestone, Bassendean / Gnangara Sands and Ascot Formation during 4 events providing a combined data set of 39, 31 and 12 samples, respectively.

Following outlier removal, UPLs were calculated for all constituents across each aquifer grouping to determine their suitability for use as environmental thresholds. The 95th percentile of concentrations was also calculated for each grouping. **Table 4-1** provides these statistics for each aquifer unit. Note that UPLs may be higher than the 95th percentile due to the distribution of the data.

Initial UPLs were previously calculated based on three rounds of data. A comparison of the initial UPL and revised UPLs is provided in **Appendix B.**

Table 4-1 Concentration Statistics for Each Aquifer Unit

Analyte	Fraction	Unit	Tamala Limestone		Ascot Formation		Bassendean / Gnangara Sand	
			95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL
Alkalinity, Bicarbonate (As CaCO3)	T	mg/L	190	295	31.6	349	12.6	167
Alkalinity, Carbonate (As CaCO3)	T	mg/L	--	--	--	--	5	5.5
Alkalinity, Total (As CaCO3)	T	mg/L	190	295	31.6	349	12.6	167
Aluminium	D	mg/L	0.01	0.04	0.01	0.03	0.01	0.6
Aluminium	T	mg/L	0.01	2	0.04	0.64	0.03	1.2
Ammonia as N	T	mg/L	0.005	0.18	0.005	0.11	0.02	0.51
Antimony	D	mg/L	0.001	0.003	0.001	0.002	--	--
Antimony	T	mg/L	0.001	0.002	0.001	0.002	0.001	0.002
Arsenic	D	mg/L	0.001	0.03	0.001	0.006	0.001	0.002
Arsenic	T	mg/L	0.001	0.03	0.002	0.006	0.001	0.006
Barium	D	mg/L	0.02	0.14	0.04	0.13	0.01	0.09
Barium	T	mg/L	0.02	0.21	0.04	0.13	0.02	0.11
Biochemical Oxygen Demand (BOD)	T	mg/L	5	28	5	19	5	62
Boron	D	mg/L	0.02	0.13	0.02	0.11	0.02	1.1
Boron	T	mg/L	0.02	0.13	0.02	0.26	0.02	1.2
Cadmium	D	mg/L	--	--	--	--	0.0001	0.0002
Cadmium	T	mg/L	0.0001	0.0002	--	--	0.0001	0.002
Calcium	D	mg/L	81.7	350	11.6	130	6.5	53.1
Cerium	D	mg/L	0.001	0.002	--	--	0.001	0.003

Analyte	Fraction	Unit	Tamala Limestone		Ascot Formation		Bassendean / Gnangara Sand	
			95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL
Cerium	T	mg/L	0.001	0.03	0.001	0.007	0.001	0.01
Chloride (As Cl)	T	mg/L	77.5	222	47.2	184	37.6	121
Chromium	T	mg/L	0.001	0.02	0.001	0.009	0.001	0.02
Chromium, total	D	mg/L	0.001	0.004	--	--	0.001	0.003
Cobalt	D	mg/L	--	--	0.001	0.001	0.001	0.005
Cobalt	T	mg/L	0.001	0.003	0.001	0.003	0.001	0.02
COD - Chemical Oxygen Demand	T	mg/L	20	330	20	23	20	100
Copper	D	mg/L	0.001	0.06	0.001	0.03	0.001	0.41
Copper	T	mg/L	0.001	0.09	0.001	0.01	0.001	0.04
Cyanide	T	mg/L	0.004	0.004	0.004	0.02	0.004	0.008
Dysprosium	T	mg/L	0.001	0.002	--	--	--	--
Ferrous Iron	T	mg/L	0.05	0.14	0.05	4.3	0.05	2.8
Fluoride	T	mg/L	0.1	0.41	0.1	0.4	0.1	0.28
Gadolinium	T	mg/L	0.001	0.002	--	--	0.001	0.001
Gallium	T	mg/L	0.001	0.002	--	--	--	--
Gross alpha particle activity	T	Bq/L	0.04	0.18	0.03	0.2	0.03	0.29
Gross beta particle activity	T	Bq/L	0.04	0.32	0.04	0.13	0.06	0.14
Hardness (As CaCO3)	D	mg/L	246	1000	54.6	400	56	250
Iron	D	mg/L	0.01	23	0.01	2	0.07	3.5
Iron	T	mg/L	0.06	16.8	0.2	7.8	0.38	7.8
Lanthanum	D	mg/L	0.0005	0.001	--	--	0.0005	0.001

Analyte	Fraction	Unit	Tamala Limestone		Ascot Formation		Bassendean / Gnangara Sand	
			95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL
Lanthanum	T	mg/L	0.0005	0.01	0.0005	0.003	0.0005	0.003
Lead	D	mg/L	--	--	--	--	0.001	0.001
Lead	T	mg/L	0.001	0.006	0.001	0.003	0.001	0.007
Lithium	D	mg/L	0.001	0.003	0.001	0.002	0.001	0.002
Lithium	T	mg/L	0.001	0.004	0.001	0.002	0.001	0.003
Magnesium	D	mg/L	9.7	40	5.9	18.7	4.8	16.2
Manganese	D	mg/L	0.001	0.03	0.001	0.57	0.002	0.04
Manganese	T	mg/L	0.003	0.12	0.005	0.57	0.004	0.02
Mercury	T	mg/L	0.00005	0.003	--	--	0.00005	0.000068
Methane	T	µg/L	--	--	5	8.2	5	1300
Molybdenum	D	mg/L	0.001	0.007	0.001	0.002	0.001	0.003
Molybdenum	T	mg/L	0.001	0.007	0.001	0.001	0.001	0.002
Neodymium	D	mg/L	--	--	--	--	0.001	0.001
Neodymium	T	mg/L	0.001	0.008	0.001	0.003	0.001	0.005
Nickel	D	mg/L	0.001	0.002	0.001	0.002	0.001	0.01
Nickel	T	mg/L	0.001	0.005	0.001	0.005	0.001	0.009
Niobium	T	mg/L	--	--	--	--	0.001	0.001
Nitrate	T	mg/L	0.14	47.4	0.1	75.7	0.02	6.3
Nitrate as N	T	mg/L	0.03	10.8	0.02	17.1	0.005	1.4
Nitrate as N + nitrite as N, preserved	T	mg/L	0.03	10.8	0.03	16.6	0.005	1.4
Nitrite	T	mg/L	0.02	0.77	0.02	0.34	0.02	0.2

Analyte	Fraction	Unit	Tamala Limestone		Ascot Formation		Bassendean / Gnangara Sand	
			95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL
Nitrite as N	T	mg/L	0.005	0.23	0.005	0.1	0.005	0.05
Nitrogen	T	mg/L	0.29	11.5	0.25	8.6	0.23	2.7
N-Nitrosodimethylamine	T	µg/L	--	--	--	--	0.01	0.03
pH	T	SU	7.1	8.1	6.7	7.8	5.5	8
Phosphate as P	T	mg/L	0.005	0.03	0.005	0.03	0.005	1.5
Phosphorus	T	mg/L	0.05	2.7	0.05	0.11	0.05	2.3
Potassium	D	mg/L	3.2	10.1	3.1	10.4	2.6	18
Praseodymium	T	mg/L	0.001	0.002	--	--	0.001	0.001
Rubidium	D	mg/L	0.003	0.01	0.004	0.007	0.004	0.02
Rubidium	T	mg/L	0.003	0.01	0.004	0.008	0.004	0.02
Samarium	T	mg/L	0.001	0.002	--	--	--	--
Scandium	T	mg/L	0.001	0.001	--	--	--	--
Selenium	D	mg/L	0.001	0.004	--	--	0.001	0.002
Selenium	T	mg/L	0.001	0.002	0.001	0.001	0.001	0.005
Silicon	D	mg/L	2.9	5.4	5	6.5	2.8	6.6
Silicon	T	mg/L	3.8	6.6	5.4	6.9	2.9	7
Sodium	D	mg/L	43.6	129	29.2	106	19.9	78.2
Sodium Adsorption Ratio	T	--	1.1	2.9	1.4	2.2	0.99	4.5
Strontium	D	mg/L	0.21	2.7	0.05	0.26	0.03	0.28
Strontium	T	mg/L	0.21	2.7	0.05	0.28	0.03	0.3
Sulfate (As SO4)	T	mg/L	34.5	640	26.2	188	1	76.6

Analyte	Fraction	Unit	Tamala Limestone		Ascot Formation		Bassendean / Gnangara Sand	
			95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL
Sulfide	T	mg/L	--	--	--	--	0.5	0.86
Sulfur	D	mg/L	13	200	9.6	57.9	0.5	26.7
Sulfur	T	mg/L	12.6	200	9.9	58.2	0.74	25.8
Sum of alpha and beta particle activity	T	Bq/L	0.04	0.38	0.05	0.34	0.04	0.49
Thallium	D	mg/L	--	--	0.001	0.001	0.001	0.002
Thallium	T	mg/L	--	--	0.001	0.002	0.001	0.003
Thorium	D	mg/L	0.0005	0.002	0.0005	0.0006	0.0005	0.0008
Thorium	T	mg/L	0.0005	0.003	0.0005	0.0009	0.0005	0.004
Tin	D	mg/L	0.001	0.001	--	--	--	--
Tin	T	mg/L	0.001	0.002	--	--	0.001	0.001
Titanium	D	mg/L	--	--	--	--	0.001	0.002
Titanium	T	mg/L	0.001	0.07	0.001	0.01	0.001	0.02
Total Carbon	T	mg/L	36.2	240	10.6	74.7	12	49.7
Total Dissolved Solids	T	mg/L	420	1093	166	837	190	409
Total Inorganic Carbon	T	mg/L	35.2	230	7.1	74.9	3.8	37.9
Total Kjeldahl Nitrogen as N	T	mg/L	0.1	1.2	0.1	1.2	0.13	1.5
Total Organic Carbon	T	mg/L	1	16	1	5	3.4	20.8
Total Suspended Solids	T	mg/L	5	446	5	41.1	5	33
Tungsten	D	mg/L	0.01	1.4	0.01	0.16	0.01	2.7
Tungsten	T	mg/L	0.01	0.02	--	--	0.01	0.42
Uranium	T	mg/L	0.001	0.001	--	--	--	--

Analyte	Fraction	Unit	Tamala Limestone		Ascot Formation		Bassendean / Gnangara Sand	
			95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL	95th %ile	Resampling[1] UPL
Vanadium	D	mg/L	0.001	0.009	--	--	0.001	0.006
Vanadium	T	mg/L	0.001	0.01	0.001	0.009	0.001	0.01
Yttrium	D	mg/L	0.001	0.002	--	--	0.001	0.003
Yttrium	T	mg/L	0.001	0.01	0.001	0.004	0.001	0.008
Zinc	D	mg/L	0.001	0.04	0.003	0.06	0.001	0.01
Zinc	T	mg/L	0.001	0.02	0.003	0.09	0.003	0.05

Table Notes:

[1] "Resampling" UPL – the concentration of a constituent at a sampling location over two consecutive sampling events should be within the UPL.

-- indicates results all below detection limit or statistics not able to be calculated due to limited data.

95%ile = 95th percentile concentration

UPL = Upper Prediction Limit

5 Suitability Assessment

After calculation of summary statistics, the suitability of reliance on each tested analyte for environmental threshold development was assessed based on criteria developed following guidance in USEPA (2009). The results of this suitability assessment are presented in **Appendix A**.

The purpose of this memo is to determine potential background monitoring thresholds (UPLs) for aquifers in the vicinity of an infiltration/injection area. This may inform the setting of discharge criteria and monitoring trigger levels in risk assessment documents. In the absence of applicable Tier 1 screening criteria for a specific constituent, UPLs may be adopted instead.

Further, while this memo sets a UPL for each constituent that formed part of the background groundwater analysis, it is anticipated that a refined analytical suite, and therefore monitoring criteria, will be specified based on the risk assessment for the proposed infiltration/injection activity. This will include consideration of the suitability assessment outlined in **Appendix A.**

6 Derivation and Proposal of Environmental Thresholds

As determined in **Appendix A**, a number of constituents have medium to high suitability for use as environmental thresholds. These UPLs can be used to:

1. Define background in the portions of the aquifer not effected by saline intrusion.
2. Identify any change in concentrations in future monitoring data that would warrant further assessment by evaluating whether changes meet standard criteria for statistical significance and align with the geochemical expectations of changes associated with any potential mixing of irrigation water. The UPLs are based on resampling (verification sampling), meaning that a statistically significant deviation from the baseline dataset will be detected only if two consecutive monitoring samples exceed the established UPL. These samples should be spaced over sufficient time to allow for statistical independence; it is anticipated that one month should be sufficient.

For a monitoring event including ten statistical tests with an α of 0.01, the likelihood of at least one false-positive exceedance (SWFPR) is 10 percent. This means that at least one exceedance of a single-constituent UPL can be expected for every ten monitoring events. The USEPA recommendation is a 10 percent annual SWFPR (USEPA, 2009). The more UPLs applied, the higher the SWFPR will be, meaning that more false-positive exceedances of single constituents are anticipated. This should be considered as part of ongoing use of PLs as environmental thresholds and supports the use of multiple lines of evidence to confirm potential impacts. Using less statistically robust analyses (such as the 95th percentile of data) is not recommended as the sole method for detection of changes as it may increase the chances of false positives and reduces the statistical power.

In addition to statistical false positives, monitoring data with concentrations above UPLs could reflect a change in conditions due to factors other than infiltration of water, such as variance in laboratory reported results, field errors, or normal seasonal or inter-annual variation that has not been captured in the baseline dataset. Given this, if PLs are exceeded, additional analysis will be triggered to determine whether the change is likely related to infiltration or to other factors. As part of this analysis, any change in the concentration of multiple analytes in the same sample will be taken into consideration as this would be expected in cases where infiltration water is infiltrating to groundwater. Multiple lines of evidence, including review of pH changes and geochemical evaluation of changes in concentration of multiple analytes, will be used to validate any suspected indicators of effects from mixing.

A number of constituents have been identified as having 'medium or low' suitability. Medium suitability results are generally due to nonparametric distributions or low detection frequencies. Power value thresholds have generally been met, and confidence is over 99% in each case. On this basis, medium suitability rated results are considered acceptable for use as environmental thresholds. Low suitability ratings are limited to cases where the power values are lower than the USEPA (2009) specifications which is attributed to lognormal distributions and larger variance in natural background groundwater quality impacting the distribution for these analytes. These values are still suitable for use but must be considered in the context of the results for other constituents which have UPLs with a high and medium suitability rating. Where UPLs have a low suitability rating and conflict with the findings for constituents with a high and medium rating then the constituents with a higher rating should be relied upon for assessment and/or a weight of evidence applied in a more detailed assessment.

7 Conclusions

Results from 82 samples which were collected from 21 monitoring wells located across five specific focus areas and screened across three aquifers were reviewed. Based on review of data consistency, 9 samples from 61419711, KW068D and KW035S were excluded from the dataset.

Environmental thresholds have been calculated based on baseline data within each aquifer; incorporating nine wells in the Tamala Limestone, three wells in the Ascot Formation and seven wells in the Bassendean/Gnangara Sands with a total of 73 samples. These background and environmental threshold values have been calculated for portions of the aquifer not affected by saline intrusion. For areas where saline intrusion is observed, higher concentrations of minor ions will be observed (above these values).

All calculated UPLs have been determined to have acceptable suitability to be used as environmental thresholds and are considered suitable for detecting changes in conditions over time. Where the suitability of the UPL is low, this should be considered when assessing exceedances in accordance with the framework described in Section 6 above. Thresholds calculated may not fully capture the range of normal seasonal and inter-annual variability associated with background conditions.

The environmental thresholds will be reviewed as part of any investigation to a potential material change to groundwater in response to environmental monitoring.

8 References

EHS Support. (2024). *Sampling, Analysis and Quality Plan (SAQP) Kwinana Refinery.*

EHS Support. (2025a). *Residue Storage Area ABC Irrigation Risk Assessment.*

EHS Support. (2025b). *DRAFT Aquifer Infiltration and Injection Technical Assessment and Risk Assessment.*

USEPA. (2009, March). Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Unified Guidance.

Appendix A Statistical Derivation Methodology

All statistical data analysis was completed using the statistical software R. UPLs were calculated using the "EnvStats" package[1] which explains prediction limits as *"A prediction interval for some population is an interval on the real line constructed so that it will contain k future observations or averages from that population with some specified probability (1 − α), where 0 < α < 1 and k is some pre-specified positive integer. The quantity (1 − α) is called the confidence coefficient or confidence level associated with the prediction interval."*

In the case of this assessment, k is equal to 2, indicating that results for two future sampling events are to be within the UPL. It is expected that the prediction limit will be substantially higher than the 95th percentile when the data are highly variable (high standard deviation), lognormally distributed, or nonparametrically-distributed with high values present in the dataset. The UPL for nonparametrically distributed datasets is the maximum concentration.

The guidance (USEPA, 2009) suggests that a minimum of at least 8 to 10 independent background observations be collected before running most statistical tests as this allows for minimally acceptable estimates of variability and evaluation of trend and goodness of fit.

Statistical power is the probability of correctly detecting a change of a specified magnitude and is distinct from the false positive rate (USEPA, 2009). The statistical power of UPLs is improved with larger sample sizes which has been achieved by incorporating four rounds of sampling data.

UPLs were derived using a re-sampling approach to maximise statistical power. In this context, re-sampling indicates that a single sample with a concentration above the UPL will not be considered an exceedance but will trigger a verification sampling event. If the concentration in the verification sample is also above the UPL the results will be considered an exceedance.

Outlier and Variance Assessment

Removal of outliers from baseline data is critical for development of reliable thresholds (USEPA, 2009). USEPA (2009) notes that if an outlier value with much higher concentration than other background observations is not removed from background prior to statistical testing, it will tend to increase both the background sample mean and standard deviation. In turn, this may substantially raise the magnitude of a parametric prediction limit calculated from that sample and limit its ability to detect changes.

To assess presence of outliers, results were pooled for each aquifer unit and log-transformed box plots reviewed for each analyte to identify potential outlying results greater than 1.5 times the interquartile range (IQR) from the median result. The following two questions were considered:

- Are there individual wells that are clearly different from the rest of the aquifer, potentially indicating that the location is not representative of the regional background?
- Are there individual data points that are clearly different from other samples, potentially indicating artifacts?

[1] Refer to the description of "predIntNorm" at https://cran.r-project.org/web/packages/EnvStats/EnvStats.pdf

Where either of the above conditions were identified, results were removed from the dataset. These instances are outlined in **Table A-1** below. These identified outlier results were excluded from UPL calculation.

Table A-1 Summary of Outliers

Location	Aquifer	Action and Rationale
KW068D	Tamala Limestone	**All results removed (4 samples)** Multiple analytes consistently above remaining background locations indicating results are not representative of regional background. Additionally, elevated EC indicates that the location is not truly representative of background within the fresh portions of the Tamala Limestone aquifer and may be impacted by other activities and/or saline intrusion.
KW035S	Tamala Limestone	**All results removed (4 samples)** Alkalinity, methane, sodium, fluoride and metals (arsenic, molybdenum, selenium) above remaining background wells. Analytes are indicative of potential anthropogenic impacts.
61419711	Bassendean / Gnangara Sand	**Round 1 Sample removed** Initial sample electrical conductivity substantially higher than remaining results indicating potential artifacts with the individual sample. Remaining samples are similar to other wells and therefore included in the dataset.

It is noted that there are statistical tests for identifying outliers (e.g. Dixon's Q-Test and Rosner's Test); however, these are not appropriate for the dataset. Dixon's test only identifies single outliers and is therefore unreliable where clustered outliers are present (i.e., KW068D results where 4 samples are elevated compared to other monitoring wells). Rosner's Test is able to detect multiple outliers, however, it requires a normally distributed dataset. The majority of the analytes have non-parametric datasets and therefore use of either test is not considered to be valuable.

The remaining data is considered suitable for the development of environmental thresholds. This includes elevated results for boron and phosphorus at SP1-1D which appears to be representative of variance within background groundwater quality as remaining analytes are consistent with the background dataset for the Bassendean / Gnangara Sands. Variance of the Tamala Limestone dataset, following removal of outliers, is visualised in **Figure A-1**.

Following removal of outliers, data were statistically assessed using an ANOVA or Kruskal-Wallis test (depending on distribution) and associated post-hoc tests (Tukey HSD or Dunn Test, depending on distribution) to confirm whether data could be pooled across wells within each aquifer unit. Statistical testing for normality and consistency between wells was conducted with an α (significance level) of 0.01.

Over 70% (Ascot Formation and Bassendean / Gnangara Sands) or 80% (Tamala Limestone) of analytes for each aquifer indicated that pooling between all wells within that aquifer is appropriate. Given that the analysis is conservative due to the high number of tests and subsequently high false positive rate, this is considered acceptable for pooling. Where testing indicates significant differences between the concentrations in certain wells for an analyte, this is attributed to the natural variation in background conditions and therefore results are retained in the aquifer group for development of UPLs.

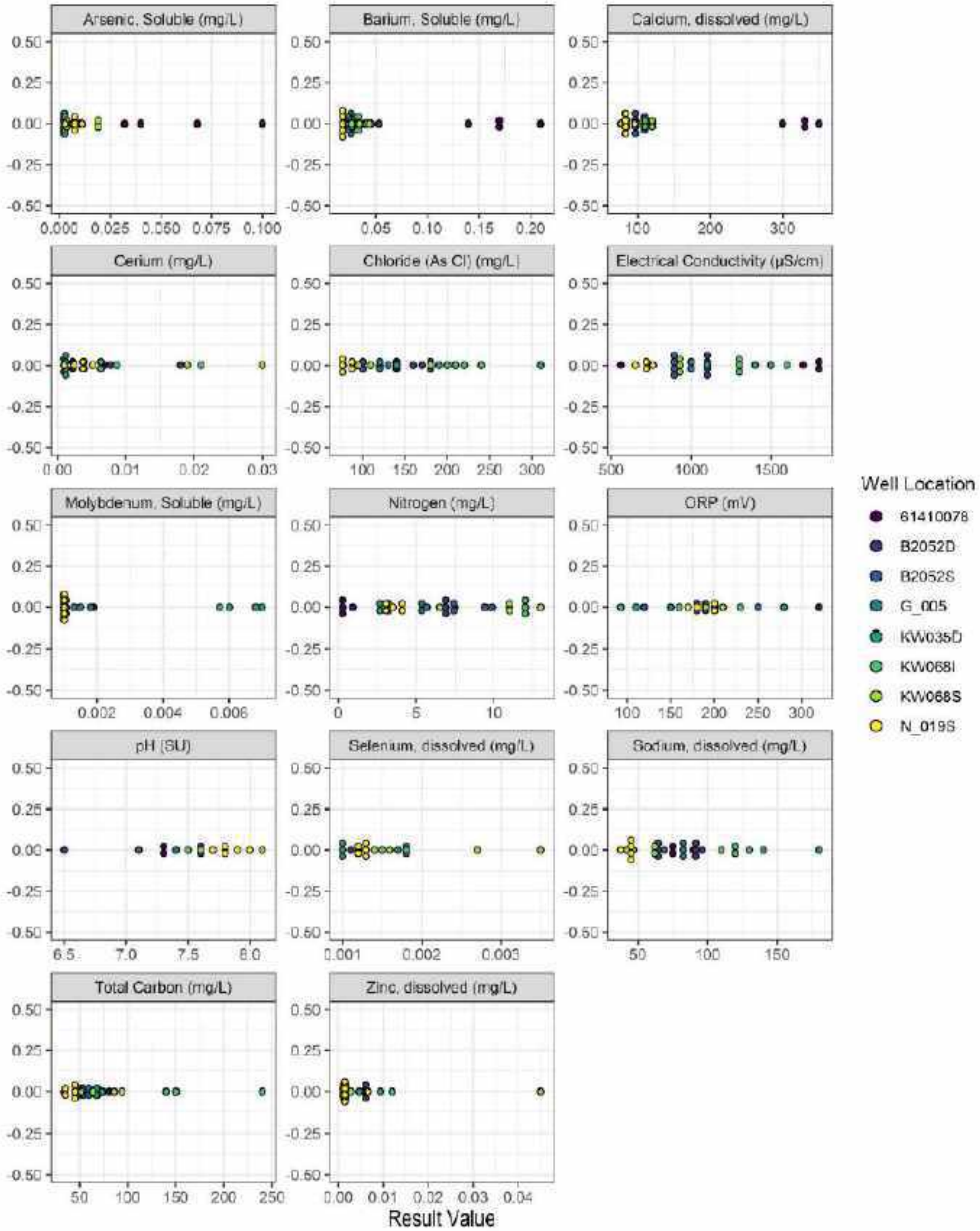


Figure A-1 Tamala Limestone Well Parameter Distribution

Suitability Assessment

After calculation of summary statistics, the suitability of reliance on each tested analyte for environmental threshold development was assessed based on criteria developed following guidance in USEPA (2009). Multiple factors were assessed to determine suitability; these factors are summarised in **Table A-2**. The results of suitability assessment are shown in **Table A-3 to Table A-5** for each aquifer unit. Consideration of all of the following factors has been used to determine the overall suitability of each UPL:

1. Detection frequency – infrequently detected analytes are generally not suitable for statistical assessment but may be used qualitatively to supplement statistical analyses. In order to improve suitability, as a conservative measure, all non-detect results have been included at the detection limit to provide sufficient data for the assessment. Therefore, UPLs with low detection frequency may still have high overall suitability, depending on the other factors.
2. Data distribution ($\alpha = 0.01$) – normally-distributed parameters lead to the most statistically powerful UPLs, and therefore highest suitability, although UPLs can be developed for lognormal and nonparametric distributions.
3. Statistical power – statistical power of UPLs was assessed using benchmarks from USEPA (2009) of at least 55 percent power to detect a three standard deviation increase in concentrations and at least 80 percent power to detect a four standard deviation increase in concentrations.
4. Confidence value of the UPL. Note that confidence values for normal and lognormal distributions are set to 99% as part of the derivation and are calculated for non-parametric distributions. All non-parametric UPLs had a confidence level >99% based on the sample size.
5. Results of the ANOVA /Kruskal-Wallis test and associated post-hoc testing. Analytes where significantly different variance was identified have lower suitability than analytes where variance is statistically similar.

Table A-2 Suitability Definitions

Factor	Suitability	Description
Sample Count	High	More than 10 samples
	Medium	8 to 10 samples
	Low	Fewer than 8 samples
Percent Detect	High	Greater than 70 percent
	Medium	50 to 70 percent
	Low	Less than 50 percent
Distribution	High	Normal distribution
	Medium	Lognormal distribution
	Low	Nonparametric distribution
Power	High	3 SD greater than 55 percent; 4 SD greater than 80 percent
	Medium	3 SD greater than 40 percent; 4 SD greater than 55 percent
	Low	3 SD less than 40 percent; 4 SD less than 55 percent
Confidence	High	Greater than 95 percent
	Medium	90 to 95 percent
	Low	Less than 90 percent
Overall Suitability	High	Power, sample count, and confidence have high suitability ratings; detection frequency, distribution and statistical support to combine wells may have medium to low suitability.
	Medium	Power, sample count, and confidence have high suitability ratings; detection frequency and distribution both have low suitability.
	Low	Power, sample count, or confidence have medium or low suitability ratings.

Table A-3 Suitability of Data for Statistical Analysis – Tamala Limestone

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Alkalinity, Bicarbonate (As $CaCO_3$)	T	31	100%	Normal	89%	99%	99%	No	High
Alkalinity, Total (As $CaCO_3$)	T	31	100%	Normal	89%	99%	99%	No	High
Aluminium	D	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Aluminium	T	31	97%	Lognormal	34%	44%	99%	No	Low
Ammonia as N	T	31	56%	Nonparametric	67%	94%	>99%	Yes	High
Antimony	D	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Antimony	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Arsenic	D	31	50%	Nonparametric	67%	94%	>99%	Yes	High
Arsenic	T	31	97%	Lognormal	33%	42%	99%	No	Low
Barium	D	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Barium	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Biochemical Oxygen Demand (BOD)	T	31	47%	Nonparametric	67%	94%	>99%	Yes	Medium
Boron	D	31	94%	Lognormal	44%	59%	99%	No	Medium
Boron	T	31	94%	Lognormal	48%	64%	99%	No	Medium
Cadmium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Calcium	D	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Cerium	D	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Cerium	T	31	72%	Nonparametric	67%	94%	>99%	Yes	High
Chloride (As Cl)	T	31	100%	Normal	89%	99%	99%	Yes	High
Chromium	T	31	81%	Lognormal	35%	46%	99%	Yes	Low
Chromium, total	D	31	6%	Nonparametric	67%	94%	>99%	Yes	Medium
Cobalt	T	31	16%	Nonparametric	67%	94%	>99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
COD - Chemical Oxygen Demand	T	31	13%	Nonparametric	67%	94%	>99%	Yes	Medium
Copper	D	31	53%	Nonparametric	67%	94%	>99%	Yes	High
Copper	T	31	56%	Nonparametric	67%	94%	>99%	Yes	High
Cyanide	T	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Dysprosium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Ferrous Iron	T	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Fluoride	T	31	47%	Nonparametric	67%	94%	>99%	Yes	Medium
Gadolinium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Gallium	T	31	13%	Nonparametric	67%	94%	>99%	Yes	Medium
Gross alpha particle activity	T	31	91%	Lognormal	41%	54%	99%	Yes	Low
Gross beta particle activity	T	31	75%	Nonparametric	67%	94%	>99%	Yes	High
Hardness (As CaCO3)	D	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Iron	D	31	19%	Nonparametric	67%	94%	>99%	Yes	Medium
Iron	T	31	100%	Lognormal	32%	40%	99%	No	Low
Lanthanum	D	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Lanthanum	T	31	72%	Nonparametric	67%	94%	>99%	Yes	High
Lead	T	31	38%	Nonparametric	67%	94%	>99%	Yes	Medium
Lithium	D	31	34%	Nonparametric	67%	94%	>99%	Yes	Medium
Lithium	T	31	66%	Nonparametric	67%	94%	>99%	Yes	High
Magnesium	D	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Manganese	D	31	56%	Nonparametric	67%	94%	>99%	Yes	High
Manganese	T	31	100%	Lognormal	35%	46%	99%	Yes	Low
Mercury	T	31	16%	Nonparametric	67%	94%	>99%	Yes	Medium
Molybdenum	D	31	41%	Nonparametric	67%	94%	>99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Molybdenum	T	31	41%	Nonparametric	67%	94%	>99%	Yes	Medium
Neodymium	T	31	50%	Nonparametric	67%	94%	>99%	Yes	High
Nickel	D	31	16%	Nonparametric	67%	94%	>99%	Yes	Medium
Nickel	T	31	47%	Nonparametric	67%	94%	>99%	Yes	Medium
Nitrate	T	31	100%	Normal	89%	99%	99%	No	High
Nitrate as N	T	31	97%	Normal	89%	99%	99%	No	High
Nitrate as N + nitrite as N, preserved	T	31	100%	Normal	89%	99%	99%	No	High
Nitrite	T	31	22%	Nonparametric	67%	94%	>99%	Yes	Medium
Nitrite as N	T	31	25%	Nonparametric	67%	94%	>99%	Yes	Medium
Nitrogen	T	31	100%	Normal	89%	99%	99%	No	High
pH	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Phosphate as P	T	31	91%	Normal	89%	99%	99%	Yes	High
Phosphorus	T	31	56%	Nonparametric	67%	94%	>99%	Yes	High
Potassium	D	31	100%	Normal	89%	99%	99%	Yes	High
Praseodymium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Rubidium	D	31	100%	Lognormal	54%	72%	99%	No	Medium
Rubidium	T	31	100%	Normal	89%	99%	99%	No	High
Samarium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Scandium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Selenium	D	31	81%	Nonparametric	67%	94%	>99%	Yes	High
Selenium	T	31	75%	Normal	89%	99%	99%	No	High
Silicon	D	31	100%	Normal	89%	99%	99%	No	High
Silicon	T	31	100%	Normal	89%	99%	99%	Yes	High
Sodium	D	31	100%	Normal	89%	99%	99%	No	High

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Sodium Adsorption Ratio	T	31	100%	Normal	89%	99%	99%	No	High
Strontium	D	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Strontium	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Sulfate (As SO4)	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Sulfur	D	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Sulfur	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Sum of alpha and beta particle activity	T	31	100%	Lognormal	40%	53%	99%	Yes	Low
Thorium	D	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Thorium	T	31	38%	Nonparametric	67%	94%	>99%	Yes	Medium
Tin	D	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Tin	T	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium
Titanium	T	31	72%	Nonparametric	67%	94%	>99%	Yes	High
Total Carbon	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Total Dissolved Solids	T	31	100%	Lognormal	56%	74%	99%	No	Medium
Total Inorganic Carbon	T	31	100%	Nonparametric	67%	94%	>99%	Yes	High
Total Kjeldahl Nitrogen as N	T	31	81%	Lognormal	39%	52%	99%	Yes	Low
Total Organic Carbon	T	31	56%	Nonparametric	67%	94%	>99%	Yes	High
Total Suspended Solids	T	31	88%	Lognormal	34%	43%	99%	No	Low
Tungsten	D	31	59%	Nonparametric	67%	94%	>99%	Yes	High
Tungsten	T	31	6%	Nonparametric	67%	94%	>99%	Yes	Medium
Uranium	T	31	9%	Nonparametric	67%	94%	>99%	Yes	Medium
Vanadium	D	31	28%	Nonparametric	67%	94%	>99%	Yes	Medium
Vanadium	T	31	94%	Lognormal	38%	50%	99%	Yes	Low
Yttrium	D	31	3%	Nonparametric	67%	94%	>99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Yttrium	T	31	56%	Nonparametric	67%	94%	>99%	Yes	High
Zinc	D	31	78%	Nonparametric	67%	94%	>99%	Yes	High
Zinc	T	31	97%	Lognormal	34%	44%	99%	Yes	Low

Table Notes:

* Confidence only applicable to analytes with nonparametric distributions. Confidence for normal and lognormal distributions are all 99%.

^Based on ANOVA or Kruskal-Wallis test with $p > 0.01$

- Colour indicates suitability for development of thresholds. Green = acceptable quality; Orange = potentially acceptable quality; Red = low quality.
- Power (%, 3 SD) denotes the statistical power of a 99% prediction limit with resampling to detect a three standard deviation change in the mean concentration.
- Power (%, 4 SD) denotes the statistical power of a 99% prediction limit with resampling to detect a four standard deviation change in the mean concentration.

Table A-4 Suitability of Data for Statistical Analysis – Ascot Formation

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Alkalinity, Bicarbonate (As CaCO3)	T	12	100%	Normal	84%	98%	99%	No	High
Alkalinity, Total (As CaCO3)	T	12	100%	Normal	84%	98%	99%	No	High
Aluminium	D	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Aluminium	T	12	100%	Lognormal	33%	44%	99%	No	Low
Ammonia as N	T	12	62%	Lognormal	30%	40%	99%	Yes	Low
Antimony	D	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Antimony	T	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Arsenic	D	12	46%	Nonparametric	81%	97%	99%	Yes	Medium
Arsenic	T	12	100%	Lognormal	39%	53%	99%	Yes	Low
Barium	D	12	100%	Nonparametric	81%	97%	99%	Yes	High
Barium	T	12	100%	Nonparametric	81%	97%	99%	Yes	High
Biochemical Oxygen Demand (BOD)	T	12	54%	Nonparametric	81%	97%	99%	Yes	High
Boron	D	12	54%	Nonparametric	81%	97%	99%	Yes	High
Boron	T	12	54%	Nonparametric	81%	97%	99%	Yes	High
Calcium	D	12	100%	Nonparametric	81%	97%	99%	Yes	High
Cerium	T	12	54%	Nonparametric	81%	97%	99%	Yes	High
Chloride (As Cl)	T	12	100%	Normal	84%	98%	99%	No	High
Chromium	T	12	54%	Nonparametric	81%	97%	99%	Yes	High
Cobalt	D	12	15%	Nonparametric	81%	97%	99%	Yes	Medium
Cobalt	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
COD - Chemical Oxygen Demand	T	12	15%	Nonparametric	81%	97%	99%	Yes	Medium
Copper	D	12	85%	Lognormal	31%	41%	99%	Yes	Low
Copper	T	12	77%	Lognormal	31%	41%	99%	No	Low

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Cyanide	T	12	15%	Nonparametric	81%	97%	99%	Yes	Medium
Ferrous Iron	T	12	46%	Nonparametric	81%	97%	99%	Yes	Medium
Fluoride	T	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Gross alpha particle activity	T	12	92%	Normal	84%	98%	99%	Yes	High
Gross beta particle activity	T	12	77%	Normal	84%	98%	99%	Yes	High
Hardness (As CaCO3)	D	12	100%	Nonparametric	81%	97%	99%	Yes	High
Iron	D	12	69%	Lognormal	27%	35%	99%	Yes	Low
Iron	T	12	100%	Lognormal	32%	42%	99%	Yes	Low
Lanthanum	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Lead	T	12	69%	Normal	84%	98%	99%	No	High
Lithium	D	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Lithium	T	12	92%	Normal	84%	98%	99%	Yes	High
Magnesium	D	12	100%	Normal	84%	98%	99%	No	High
Manganese	D	12	100%	Lognormal	31%	41%	99%	No	Low
Manganese	T	12	100%	Lognormal	32%	42%	99%	No	Low
Methane	T	12	23%	Nonparametric	81%	97%	99%	Yes	Medium
Molybdenum	D	12	23%	Nonparametric	81%	97%	99%	Yes	Medium
Molybdenum	T	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Neodymium	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Nickel	D	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Nickel	T	12	46%	Nonparametric	81%	97%	99%	Yes	Medium
Nitrate	T	12	100%	Lognormal	31%	41%	99%	No	Low
Nitrate as N	T	12	100%	Lognormal	31%	41%	99%	No	Low
Nitrate as N + nitrite as N, preserved	T	12	100%	Lognormal	31%	41%	99%	No	Low
Nitrite	T	12	46%	Nonparametric	81%	97%	99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Nitrite as N	T	12	46%	Nonparametric	81%	97%	99%	Yes	Medium
Nitrogen	T	12	100%	Nonparametric	81%	97%	99%	Yes	High
pH	T	12	100%	Normal	84%	98%	99%	Yes	High
Phosphate as P	T	12	69%	Normal	84%	98%	99%	Yes	High
Phosphorus	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Potassium	D	12	100%	Lognormal	43%	59%	99%	Yes	Medium
Rubidium	D	12	100%	Normal	84%	98%	99%	Yes	High
Rubidium	T	12	100%	Normal	84%	98%	99%	Yes	High
Selenium	T	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Silicon	D	12	100%	Normal	84%	98%	99%	Yes	High
Silicon	T	12	100%	Normal	84%	98%	99%	Yes	High
Sodium	D	12	100%	Normal	84%	98%	99%	No	High
Sodium Adsorption Ratio	T	12	100%	Normal	84%	98%	99%	No	High
Strontium	D	12	100%	Nonparametric	81%	97%	99%	Yes	High
Strontium	T	12	100%	Nonparametric	81%	97%	99%	Yes	High
Sulfate (As SO4)	T	12	100%	Lognormal	39%	54%	99%	No	Low
Sulfur	D	12	100%	Lognormal	40%	55%	99%	No	Medium
Sulfur	T	12	100%	Lognormal	40%	55%	99%	No	Medium
Sum of alpha and beta particle activity	T	12	100%	Normal	83%	98%	99%	Yes	High
Thallium	D	12	23%	Nonparametric	81%	97%	99%	Yes	Medium
Thallium	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Thorium	D	12	8%	Nonparametric	81%	97%	99%	Yes	Medium
Thorium	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Titanium	T	12	100%	Lognormal	33%	44%	99%	No	Low
Total Carbon	T	12	100%	Normal	84%	98%	99%	No	High

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Total Dissolved Solids (Residue, Filterable)	T	12	100%	Normal	84%	98%	99%	No	High
Total Inorganic Carbon	T	12	100%	Normal	84%	98%	99%	No	High
Total Kjeldahl Nitrogen as N	T	12	92%	Normal	84%	98%	99%	No	High
Total Organic Carbon	T	12	62%	Lognormal	39%	53%	99%	No	Low
Total Suspended Solids	T	12	54%	Lognormal	34%	46%	99%	Yes	Low
Tungsten	D	12	38%	Nonparametric	81%	97%	99%	Yes	Medium
Vanadium	T	12	77%	Nonparametric	81%	97%	99%	Yes	High
Yttrium	T	12	31%	Nonparametric	81%	97%	99%	Yes	Medium
Zinc	D	12	100%	Lognormal	32%	43%	99%	No	Low
Zinc	T	12	100%	Lognormal	30%	40%	99%	No	Low

Table Notes:

* Confidence only applicable to analytes with nonparametric distributions. Confidence for normal and lognormal distributions are all 99%.

^Based on ANOVA or Kruskal-Wallis test with $p > 0.01$

- Colour indicates suitability for development of thresholds. Green = acceptable quality; Orange = potentially acceptable quality; Red = low quality.
- Power (%, 3 SD) denotes the statistical power of a 99% prediction limit with resampling to detect a three standard deviation change in the mean concentration.
- Power (%, 4 SD) denotes the statistical power of a 99% prediction limit with resampling to detect a four standard deviation change in the mean concentration.

Table A-5 Suitability of Data for Statistical Analysis – Bassendean Sand / Gnangara Sand

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Alkalinity, Bicarbonate (As CaCO3)	T	30	100%	Lognormal	41%	54%	99%	No	Low
Alkalinity, Carbonate (As CaCO3)	T	30	3%	Nonparametric	68%	94%	>99%	Yes	Medium
Alkalinity, Total (As CaCO3)	T	30	100%	Lognormal	41%	54%	99%	No	Low
Aluminium	D	30	70%	Nonparametric	68%	94%	>99%	Yes	High
Aluminium	T	30	100%	Lognormal	37%	49%	99%	Yes	Low
Ammonia as N	T	30	100%	Lognormal	41%	55%	99%	No	Medium
Antimony	T	30	3%	Nonparametric	69%	94%	>99%	Yes	Medium
Arsenic	D	30	30%	Nonparametric	68%	94%	>99%	Yes	Medium
Arsenic	T	30	62%	Nonparametric	69%	94%	>99%	Yes	High
Barium	D	30	100%	Lognormal	45%	60%	99%	No	Medium
Barium	T	30	100%	Lognormal	46%	61%	99%	No	Medium
Biochemical Oxygen Demand (BOD)	T	30	53%	Nonparametric	68%	94%	>99%	Yes	High
Boron	D	30	57%	Nonparametric	68%	94%	>99%	Yes	High
Boron	T	30	59%	Nonparametric	69%	94%	>99%	Yes	High
Cadmium	D	30	7%	Nonparametric	68%	94%	>99%	Yes	Medium
Cadmium	T	30	7%	Nonparametric	69%	94%	>99%	Yes	Medium
Calcium	D	30	100%	Lognormal	42%	56%	99%	No	Medium
Cerium	D	30	27%	Nonparametric	68%	94%	>99%	Yes	Medium
Cerium	T	30	72%	Nonparametric	69%	94%	>99%	Yes	High
Chloride (As Cl)	T	30	100%	Normal	89%	99%	99%	No	High
Chromium	T	30	90%	Nonparametric	69%	94%	>99%	Yes	High
Chromium, total	D	30	33%	Nonparametric	68%	94%	>99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Cobalt	D	30	10%	Nonparametric	68%	94%	>99%	Yes	Medium
Cobalt	T	30	10%	Nonparametric	69%	94%	>99%	Yes	Medium
COD - Chemical Oxygen Demand	T	30	43%	Nonparametric	68%	94%	>99%	Yes	Medium
Copper	D	30	67%	Nonparametric	68%	94%	>99%	Yes	High
Copper	T	30	62%	Nonparametric	69%	94%	>99%	Yes	High
Cyanide	T	30	7%	Nonparametric	68%	94%	>99%	Yes	Medium
Ferrous Iron	T	30	73%	Lognormal	38%	50%	99%	Yes	Low
Fluoride	T	30	30%	Nonparametric	68%	94%	>99%	Yes	Medium
Gadolinium	T	30	3%	Nonparametric	69%	94%	>99%	Yes	Medium
Gross alpha particle activity	T	30	77%	Lognormal	37%	48%	99%	No	Low
Gross beta particle activity	T	30	70%	Normal	89%	99%	99%	Yes	High
Hardness (As CaCO3)	D	30	100%	Nonparametric	68%	94%	>99%	Yes	High
Iron	D	30	100%	Lognormal	39%	52%	99%	Yes	Low
Iron	T	30	100%	Lognormal	40%	53%	99%	No	Low
Lanthanum	D	30	30%	Nonparametric	68%	94%	>99%	Yes	Medium
Lanthanum	T	30	72%	Lognormal	40%	53%	99%	Yes	Low
Lead	D	30	7%	Nonparametric	68%	94%	>99%	Yes	Medium
Lead	T	30	62%	Nonparametric	69%	94%	>99%	Yes	High
Lithium	D	30	50%	Nonparametric	68%	94%	>99%	Yes	High
Lithium	T	30	62%	Nonparametric	69%	94%	>99%	Yes	High
Magnesium	D	30	100%	Normal	89%	99%	99%	No	High
Manganese	D	30	97%	Nonparametric	68%	94%	>99%	Yes	High
Manganese	T	30	100%	Lognormal	48%	65%	99%	No	Medium
Mercury	T	30	3%	Nonparametric	69%	94%	>99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Methane	T	30	33%	Nonparametric	68%	94%	>99%	Yes	Medium
Molybdenum	D	30	10%	Nonparametric	68%	94%	>99%	Yes	Medium
Molybdenum	T	30	7%	Nonparametric	69%	94%	>99%	Yes	Medium
Neodymium	D	30	7%	Nonparametric	68%	94%	>99%	Yes	Medium
Neodymium	T	30	41%	Nonparametric	69%	94%	>99%	Yes	Medium
Nickel	D	30	27%	Nonparametric	68%	94%	>99%	Yes	Medium
Nickel	T	30	52%	Nonparametric	69%	94%	>99%	Yes	High
Niobium	T	30	3%	Nonparametric	69%	94%	>99%	Yes	Medium
Nitrate	T	30	77%	Lognormal	32%	41%	99%	No	Low
Nitrate as N	T	30	77%	Lognormal	32%	41%	99%	No	Low
Nitrate as N + nitrite as N, preserved	T	30	77%	Lognormal	32%	41%	99%	No	Low
Nitrite	T	30	17%	Nonparametric	68%	94%	>99%	Yes	Medium
Nitrite as N	T	30	23%	Nonparametric	68%	94%	>99%	Yes	Medium
Nitrogen	T	30	100%	Lognormal	39%	52%	99%	No	Low
N-Nitrosodimethylamine	T	30	10%	Nonparametric	68%	94%	>99%	Yes	Medium
pH	T	30	100%	Normal	89%	99%	99%	No	High
Phosphate as P	T	30	73%	Nonparametric	68%	94%	>99%	No	High
Phosphorus	T	30	53%	Nonparametric	68%	94%	>99%	Yes	High
Potassium	D	30	100%	Nonparametric	68%	94%	>99%	Yes	High
Praseodymium	T	30	3%	Nonparametric	69%	94%	>99%	Yes	Medium
Rubidium	D	30	100%	Nonparametric	68%	94%	>99%	Yes	High
Rubidium	T	30	100%	Nonparametric	69%	94%	>99%	Yes	High
Selenium	D	30	7%	Nonparametric	68%	94%	>99%	Yes	Medium
Selenium	T	30	17%	Nonparametric	69%	94%	>99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Silicon	D	30	100%	Normal	89%	99%	99%	No	High
Silicon	T	30	100%	Normal	89%	99%	99%	No	High
Sodium	D	30	100%	Normal	89%	99%	99%	No	High
Sodium Adsorption Ratio	T	30	100%	Nonparametric	68%	94%	>99%	Yes	High
Strontium	D	30	100%	Lognormal	39%	52%	99%	No	Low
Strontium	T	30	100%	Lognormal	39%	51%	99%	No	Low
Sulfate (As SO4)	T	30	90%	Normal	89%	99%	99%	No	High
Sulfide	T	30	10%	Nonparametric	68%	94%	>99%	Yes	Medium
Sulfur	D	30	90%	Normal	89%	99%	99%	No	High
Sulfur	T	30	97%	Normal	89%	99%	99%	No	High
Sum of alpha and beta particle activity	T	30	100%	Lognormal	40%	53%	99%	Yes	Low
Thallium	D	30	10%	Nonparametric	68%	94%	>99%	Yes	Medium
Thallium	T	30	14%	Nonparametric	69%	94%	>99%	Yes	Medium
Thorium	D	30	7%	Nonparametric	68%	94%	>99%	Yes	Medium
Thorium	T	30	41%	Nonparametric	69%	94%	>99%	Yes	Medium
Tin	T	30	3%	Nonparametric	69%	94%	>99%	Yes	Medium
Titanium	D	30	10%	Nonparametric	68%	94%	>99%	Yes	Medium
Titanium	T	30	83%	Nonparametric	69%	94%	>99%	Yes	High
Total Carbon	T	30	100%	Lognormal	46%	62%	99%	No	Medium
Total Dissolved Solids	T	30	100%	Normal	89%	99%	99%	Yes	High
Total Inorganic Carbon	T	30	100%	Lognormal	40%	54%	99%	No	Low
Total Kjeldahl Nitrogen as N	T	30	93%	Lognormal	43%	58%	99%	No	Medium
Total Organic Carbon	T	30	100%	Lognormal	41%	55%	99%	No	Medium
Total Suspended Solids	T	30	87%	Lognormal	42%	56%	99%	Yes	Medium

Analyte	Fraction	Sample Count	Percent Detect	Distribution	Power (%, 3 SD)	Power (%, 4 SD)	Confidence*	Statistical support for combining wells^	Overall Suitability
Tungsten	D	30	57%	Nonparametric	68%	94%	>99%	Yes	High
Tungsten	T	30	10%	Nonparametric	69%	94%	>99%	Yes	Medium
Vanadium	D	30	60%	Nonparametric	68%	94%	>99%	Yes	High
Vanadium	T	30	100%	Lognormal	38%	51%	99%	No	Low
Yttrium	D	30	27%	Nonparametric	68%	94%	>99%	Yes	Medium
Yttrium	T	30	41%	Nonparametric	69%	94%	>99%	Yes	Medium
Zinc	D	30	97%	Lognormal	42%	56%	99%	Yes	Medium
Zinc	T	30	100%	Lognormal	35%	45%	99%	Yes	Low

Table Notes:
* Confidence only applicable to analytes with nonparametric distributions. Confidence for normal and lognormal distributions are all 99%.
^Based on ANOVA or Kruskal-Wallis test with p > 0.01
- Colour indicates suitability for development of thresholds. Green = acceptable quality; Orange = potentially acceptable quality; Red = low quality.
- Power (%, 3 SD) denotes the statistical power of a 99% prediction limit with resampling to detect a three standard deviation change in the mean concentration.
- Power (%, 4 SD) denotes the statistical power of a 99% prediction limit with resampling to detect a four standard deviation change in the mean concentration.

Appendix B Comparison of Initial and Revised Prediction Limits

Initial Upper Prediction Limits (UPLs) were calculated based on three rounds of sampling data. Given the limited dataset, quantitative analysis of variance could not be completed previously, as noted in Revision 2 of this document. A summary of initial UPLs compared to revised UPLs is provided in **Table B-1**.

Note that the initial calculation of the UPLs was based on a qualitative outlier and variance assessment. The completion of the fourth round provided sufficient sampling rounds for a quantitative assessment. Quantitative assessment resulted in the exclusion of additional results from the dataset which resulted in a significant decline in the UPLs for certain analytes. Other analytes, not affected by this change, exhibited a smaller quantum of variation (both positive and negative) reflective of adding a further round of sampling to a dataset. The net result of the additional sampling round and the application of quantitative outlier assessments have provided significant improvements in the confidence level and suitability of the UPLs for application.

It is unlikely that similar substantial revisions of UPLs will occur as future monitoring events are added to the UPL dataset as the variance within the data sets are constrained, quantitative outlier analysis and exclusion has been completed and revised UPLs are now confirmed to be of acceptable quality.

Table B-1 Comparison of Initial and Revised PLs

Analyte	Fraction	Unit	Tamala Limestone			Ascot Formation			Bassendean / Gnangara Sand		
			Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference
Alkalinity, Bicarbonate (As CaCO3)	T	mg/L	890	295	-595	571	349	-222	726	167	-559
Alkalinity, Carbonate (As CaCO3)	T	mg/L	--	--	--	--	--	--	5.5	5.5	0
Alkalinity, Total (As CaCO3)	T	mg/L	890	295	-595	571	349	-222	726	167	-559
Aluminium	D	mg/L	0.032	0.04	0.008	0.032	0.03	-0.002	0.6	0.6	0
Aluminium	T	mg/L	22.464	2	-20.464	1.075	0.64	-0.435	6.854	1.2	-5.654
Ammonia as N	T	mg/L	0.32	0.18	-0.14	1.947	0.11	-1.837	0.62	0.51	-0.11
Antimony	D	mg/L	0.0028	0.003	0.0002	0.0017	0.002	0.0003	--	--	--
Antimony	T	mg/L	0.0023	0.002	-0.0003	0.002	0.002	0	0.0015	0.002	0.0005
Arsenic	D	mg/L	0.13	0.03	-0.1	0.0064	0.006	-0.0004	0.0024	0.002	-0.0004
Arsenic	T	mg/L	0.57	0.03	-0.54	0.0232	0.006	-0.0172	0.006	0.006	0
Barium	D	mg/L	0.14	0.14	0	0.273	0.13	-0.143	0.224	0.09	-0.134
Barium	T	mg/L	0.21	0.21	0	0.175	0.13	-0.045	0.264	0.11	-0.154
Biochemical Oxygen Demand (BOD)	T	mg/L	28	28	0	32.126	19	-13.126	20.795	62	41.205
Boron	D	mg/L	0.512	0.13	-0.382	0.11	0.11	0	1.1	1.1	0
Boron	T	mg/L	0.226	0.13	-0.096	0.26	0.26	0	1.2	1.2	0
Cadmium	D	mg/L	--	--	--	--	--	--	0.00025	0.0002	-0.00005
Cadmium	T	mg/L	0.00016	0.0002	0.00004	--	--	--	0.0016	0.002	0.0004
Calcium	D	mg/L	330	350	20	263.521	130	-133.521	132.667	53.1	-79.567
Cerium	D	mg/L	0.0019	0.002	0.0001	--	--	--	0.003	0.003	0
Cerium	T	mg/L	0.0728	0.03	-0.0428	0.0069	0.007	0.0001	0.0183	0.01	-0.0083
Chloride (As Cl)	T	mg/L	267	222	-45	280.221	184	-96.221	140.63	121	-19.63
Chromium	T	mg/L	0.115	0.02	-0.095	0.0424	0.009	-0.0334	0.0321	0.02	-0.0121
Chromium, total	D	mg/L	0.0045	0.004	-0.0005	--	--	--	0.0026	0.003	0.0004
Cobalt	D	mg/L	--	--	--	0.0011	0.001	-0.0001	0.0054	0.005	-0.0004
Cobalt	T	mg/L	0.0027	0.003	0.0003	0.0033	0.003	-0.0003	0.016	0.02	0.004
COD - Chemical Oxygen Demand	T	mg/L	0.33	330	329.67	0.023	23	22.977	0.084	100	99.916
Copper	D	mg/L	0.067	0.06	-0.007	0.382	0.03	-0.352	0.41	0.41	0
Copper	T	mg/L	0.089	0.09	0.001	0.0874	0.01	-0.0774	0.014	0.04	0.026
Cyanide	T	mg/L	0.0044	0.004	-0.0004	0.021	0.02	-0.001	0.0082	0.008	-0.0002

Analyte	Fraction	Unit	Tamala Limestone			Ascot Formation			Bassendean / Gnangara Sand		
			Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference
Dysprosium	T	mg/L	0.0016	0.002	0.0004	--	--	--	--	--	--
Ferrous Iron	T	mg/L	0.14	0.14	0	75.96	4.3	-71.66	17.911	2.8	-15.111
Fluoride	T	mg/L	1.7	0.41	-1.29	0.4	0.4	0	0.28	0.28	0
Gadolinium	T	mg/L	0.0018	0.002	0.0002	--	--	--	0.0011	0.001	-0.0001
Gallium	T	mg/L	0.0021	0.002	-1E-04	--	--	--	--	--	--
Gross alpha particle activity	T	Bq/L	0.39	0.18	-0.21	0.37	0.2	-0.17	1.4	0.29	-1.11
Gross beta particle activity	T	Bq/L	0.32	0.32	0	0.21	0.13	-0.08	0.2	0.14	-0.06
Hardness (As CaCO3)	D	mg/L	960	1000	40	771.801	400	-371.801	200	250	50
Iron	D	mg/L	23	23	0	296	2	-294	4.506	3.5	-1.006
Iron	T	mg/L	186	16.8	-169.2	11	7.8	-3.2	25	7.8	-17.2
Lanthanum	D	mg/L	0.0012	0.001	-0.0002	--	--	--	0.0013	0.001	-0.0003
Lanthanum	T	mg/L	0.0262	0.01	-0.0162	0.0034	0.003	-0.0004	0.0091	0.003	-0.0061
Lead	D	mg/L	--	--	--	--	--	--	0.0012	0.001	-0.0002
Lead	T	mg/L	0.0059	0.006	0.0001	0.0051	0.003	-0.0021	0.0113	0.007	-0.0043
Lithium	D	mg/L	0.0031	0.003	-1E-04	0.0018	0.002	0.0002	0.0021	0.002	-1E-04
Lithium	T	mg/L	0.0039	0.004	0.0001	0.0031	0.002	-0.0011	0.0028	0.003	0.0002
Magnesium	D	mg/L	31	40	9	27	18.7	-8.3	24	16.2	-7.8
Manganese	D	mg/L	0.032	0.03	-0.002	33	0.57	-32.43	0.0451	0.04	-0.0051
Manganese	T	mg/L	0.86	0.12	-0.74	16	0.57	-15.43	0.0242	0.02	-0.0042
Mercury	T	mg/L	0.0027	0.003	0.0003	--	--	--	0.00007	0.000068	-2E-06
Methane	T	µg/L	14	--	--	8.2	8.2	0	640	1300	660
Molybdenum	D	mg/L	0.26	0.007	-0.253	0.0015	0.002	0.0005	0.0031	0.003	-1E-04
Molybdenum	T	mg/L	0.27	0.007	-0.263	0.0011	0.001	-0.0001	0.0024	0.002	-0.0004
Neodymium	D	mg/L	--	--	--	--	--	--	0.0014	0.001	-0.0004
Neodymium	T	mg/L	0.0084	0.008	-0.0004	0.003	0.003	0	0.0054	0.005	-0.0004
Nickel	D	mg/L	0.0021	0.002	-1E-04	0.0022	0.002	-0.0002	0.0037	0.01	0.0063
Nickel	T	mg/L	0.0051	0.005	-0.0001	0.0123	0.005	-0.0073	0.006	0.009	0.003
Niobium	T	mg/L	--	--	--	--	--	--	0.0012	0.001	-0.0002
Nitrate	T	mg/L	75	47.4	-27.6	9810	75.7	-9734.3	187	6.3	-180.7
Nitrate as N	T	mg/L	17	10.8	-6.2	2190	17.1	-2172.9	40	1.4	-38.6
Nitrate as N + nitrite as N, preserved	T	mg/L	17	10.8	-6.2	1877	16.6	-1860.4	41	1.4	-39.6

Analyte	Fraction	Unit	Tamala Limestone			Ascot Formation			Bassendean / Gnangara Sand		
			Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference
Nitrite	T	mg/L	0.77	0.77	0	0.34	0.34	0	0.2	0.2	0
Nitrite as N	T	mg/L	0.23	0.23	0	0.1	0.1	0	0.05	0.05	0
Nitrogen	T	mg/L	18	11.5	-6.5	237	8.6	-228.4	11.129	2.7	-8.429
N-Nitrosodimethylamine	T	µg/L	--	--	--	--	--	--	0.03	0.03	0
pH	T	SU	8	8.1	0.1	8.3	7.8	-0.5	9.2	8	-1.2
Phosphate as P	T	mg/L	0.183	0.03	-0.153	0.0643	0.03	-0.0343	1.4	1.5	0.1
Phosphorus	T	mg/L	2.7	2.7	0	0.11	0.11	0	2.2	2.3	0.1
Potassium	D	mg/L	13.5	10.1	-3.4	18.4	10.4	-8	41.3	18	-23.3
Praseodymium	T	mg/L	0.0023	0.002	-0.0003	--	--	--	0.0014	0.001	-0.0004
Rubidium	D	mg/L	0.0142	0.01	-0.0042	0.009	0.007	-0.002	0.021	0.02	-0.001
Rubidium	T	mg/L	0.0151	0.01	-0.0051	0.0099	0.008	-0.0019	0.022	0.02	-0.002
Samarium	T	mg/L	0.0017	0.002	0.0003	--	--	--	--	--	--
Scandium	T	mg/L	0.0013	0.001	-0.0003	--	--	--	--	--	--
Selenium	D	mg/L	0.012	0.004	-0.008	--	--	--	0.0018	0.002	0.0002
Selenium	T	mg/L	0.015	0.002	-0.013	0.0014	0.001	-0.0004	0.0052	0.005	-0.0002
Silicon	D	mg/L	6.6	5.4	-1.2	7.12	6.5	-0.62	8.5	6.6	-1.9
Silicon	T	mg/L	8.53	6.6	-1.93	7.36	6.9	-0.46	9.52	7	-2.52
Sodium	D	mg/L	680	129	-551	156	106	-50	104	78.2	-25.8
Sodium Adsorption Ratio	T	--	20	2.9	-17.1	2.6	2.2	-0.4	6.1	4.5	-1.6
Strontium	D	mg/L	2.4	2.7	0.3	0.493	0.26	-0.233	1.021	0.28	-0.741
Strontium	T	mg/L	4.092	2.7	-1.392	0.507	0.28	-0.227	1.242	0.3	-0.942
Sulfate (As SO4)	T	mg/L	640	640	0	721	188	-533	117	76.6	-40.4
Sulfide	T	mg/L	--	--	--	--	--	--	0.82	0.86	0.04
Sulfur	D	mg/L	200	200	0	188	57.9	-130.1	41	26.7	-14.3
Sulfur	T	mg/L	200	200	0	78	58.2	-19.8	39	25.8	-13.2
Sum of alpha and beta particle activity	T	Bq/L	1.1	0.38	-0.72	0.55	0.34	-0.21	1.9	0.49	-1.41
Thallium	D	mg/L	--	--	--	0.0012	0.001	-0.0002	0.002	0.002	0
Thallium	T	mg/L	--	--	--	0.0016	0.002	0.0004	0.003	0.003	0
Thorium	D	mg/L	0.0015	0.002	0.0005	0.00058	0.0006	2E-05	0.00085	0.0008	-5E-05
Thorium	T	mg/L	0.0031	0.003	-1E-04	0.00093	0.0009	-3E-05	0.0037	0.004	0.0003
Tin	D	mg/L	0.0011	0.001	-0.0001	--	--	--	--	--	--

Analyte	Fraction	Unit	Tamala Limestone			Ascot Formation			Bassendean / Gnangara Sand		
			Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference	Initial UPL	Revised UPL	Difference
Tin	T	mg/L	0.0022	0.002	-0.0002	--	--	--	0.0013	0.001	-0.0003
Titanium	D	mg/L	--	--	--	--	--	--	--	0.002	--
Titanium	T	mg/L	0.392	0.07	-0.322	0.0737	0.01	-0.0637	0.0295	0.02	-0.0095
Total Carbon	T	mg/L	260	240	-20	107	74.7	-32.3	100	49.7	-50.3
Total Dissolved Solids	T	mg/L	2834	1093	-1741	1270	837	-433	511	409	-102
Total Inorganic Carbon	T	mg/L	230	230	0	110	74.9	-35.1	173	37.9	-135.1
Total Kjeldahl Nitrogen as N	T	mg/L	5.52	1.2	-4.32	2.13	1.2	-0.93	1.9	1.5	-0.4
Total Organic Carbon	T	mg/L	16	16	0	9	5	-4	21	20.8	-0.2
Total Suspended Solids	T	mg/L	5590	446	-5144	80	41.1	-38.9	90	33	-57
Tungsten	D	mg/L	1.4	1.4	0	0.16	0.16	0	2.7	2.7	0
Tungsten	T	mg/L	0.02	0.02	0	--	--	--	0.013	0.42	0.407
Uranium	D	mg/L	0.0075	--	--	--	--	--	--	--	--
Uranium	T	mg/L	0.008	0.001	-0.007	--	--	--	--	--	--
Vanadium	D	mg/L	0.0091	0.009	-0.0001	--	--	--	0.0058	0.006	0.0002
Vanadium	T	mg/L	0.0534	0.01	-0.0434	0.0314	0.009	-0.0224	0.0481	0.01	-0.0381
Yttrium	D	mg/L	0.0022	0.002	-0.0002	--	--	--	0.0026	0.003	0.0004
Yttrium	T	mg/L	0.012	0.01	-0.002	0.004	0.004	0	0.0077	0.008	0.0003
Zinc	D	mg/L	0.043	0.04	-0.003	0.0713	0.06	-0.0113	0.0142	0.01	-0.0042
Zinc	T	mg/L	0.117	0.02	-0.097	0.104	0.09	-0.014	0.432	0.05	-0.382

Appendix B Pilot Plant – Analytical Results

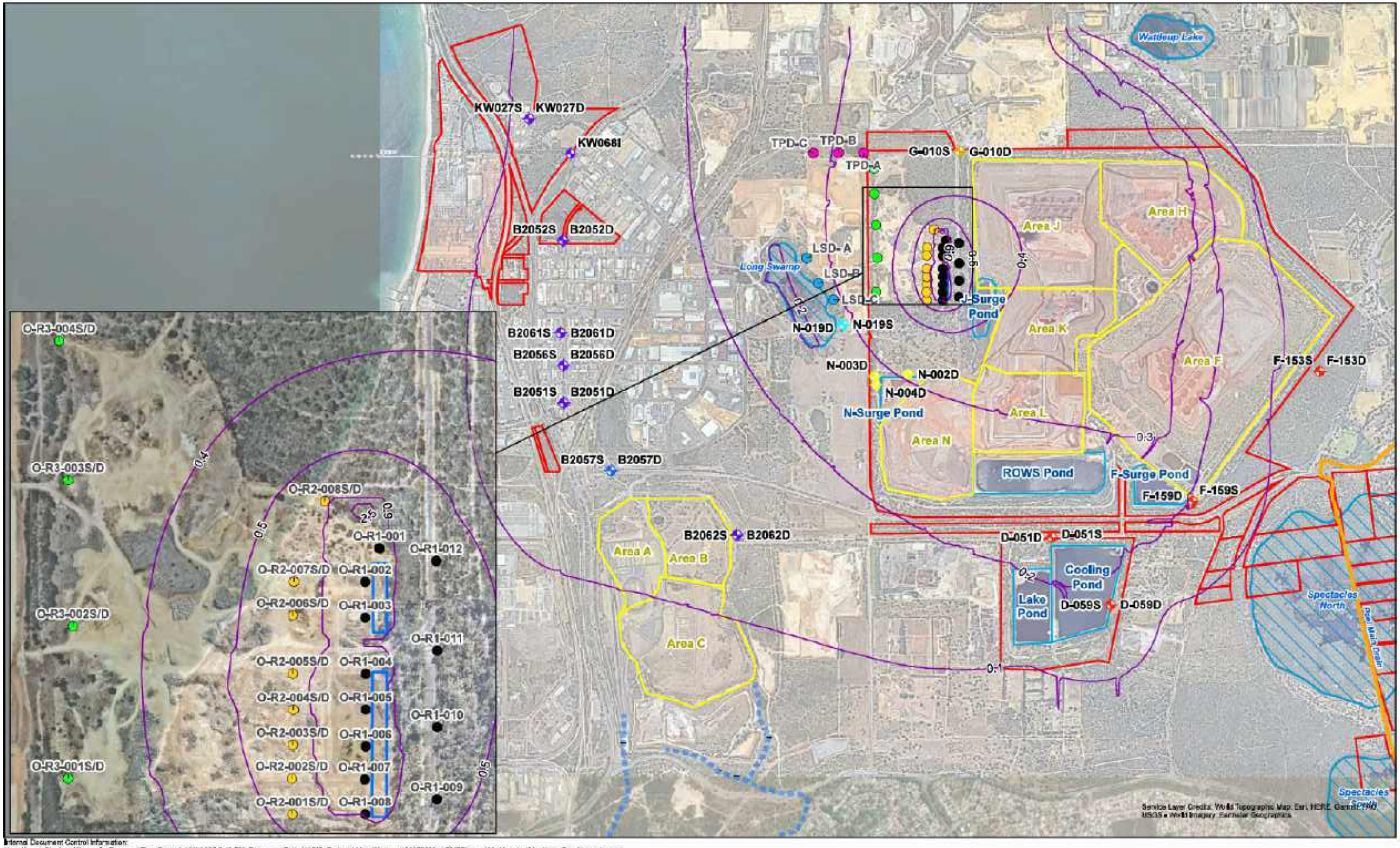
Appendix D
Table D1
Pilot Plant Analytical Results
Alcoa Kwinana Monitoring and Management Plan

Analyte	Fraction	DWER (2021) RPUS	EHS Support Tamala Limestone LR99	Unit	Clarifier Overflow Range	Clarifier Overflow Detect / Sample Count	Neutralised Feed Range	Neutralised Feed Detect / Sample Count	Media Filtrate Range	Media Filtrate Detect / Sample Count	UF Filtrate Range	UF Filtrate Detect / Sample Count	RO Permeate Range	RO Permeate Detect / Sample Count
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3
2,4,5-Trichlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2,4,6-Trichlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2,4-Dichlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2,4-Dimethylphenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2,4-Dinitrophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2,6-Dichlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3
2,3,4,5 & 2,3,4,6-Tetrachlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2-Chlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2-Cyclohexyl-4,6-Dinitrophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2-Methylphenol (O-Cresol)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
2-Nitrophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
3- & 4-Methylphenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
4,6-Dinitro-2-Methylphenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
4-Chloro-3-Methylphenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
4-Nitrophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND - 0.00062	2 / 3	ND	0 / 3	ND	0 / 3
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Acetone	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3
Alkalinity, Bicarbonate (As CaCO3)	T	–	235	mg/L	5300 - 8000	3 / 3	4900 - 7900	3 / 3	5100 - 7600	3 / 3	210 - 8200	3 / 3	ND - 73	3 / 4
Alkalinity, Carbonate (As CaCO3)	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 63	1 / 3	ND	0 / 4
Alkalinity, Hydroxide (As CaCO3)	T	–	–	mg/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Alkalinity, Total (As CaCO3)	T	–	396	mg/L	5300 - 8000	3 / 3	4600 - 7900	3 / 3	5100 - 7600	3 / 3	210 - 8200	3 / 3	ND - 79	3 / 4
alpha BHC (Alpha Hexachlorocyclohexane)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Alpha Endosulfan	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Aluminium	D	0.2	0.08	mg/L	4.7 - 8.7	3 / 3	4 - 9	3 / 3	4.1 - 8.8	3 / 3	0.026 - 4.9	3 / 3	ND - 0.023	3 / 4
Aluminium	T	0.2	3	mg/L	12 - 32	3 / 3	36 - 110	3 / 3	6.7 - 10	3 / 3	0.086 - 5.4	3 / 3	ND - 0.023	3 / 4
Ammonia as N	T	–	0.18	mg/L	0.32 - 0.67	3 / 3	0.028 - 0.25	3 / 3	0.018 - 0.03	3 / 3	0.059 - 0.59	3 / 3	0.0092 - 0.13	4 / 4
Antimony	D	0.02	0.003	mg/L	0.0013 - 0.0013	3 / 3	0.0012 - 0.0014	3 / 3	0.0011 - 0.0012	3 / 3	ND - 0.0012	2 / 3	ND	0 / 4
Antimony	T	0.03	0.002	mg/L	0.001 - 0.0025	3 / 3	ND - 0.0017	2 / 3	ND - 0.0025	2 / 3	ND - 0.0024	1 / 3	ND	0 / 4
Arsenic	D	0.1	0.03	mg/L	0.091 - 0.13	3 / 3	0.089 - 0.11	3 / 3	0.086 - 0.13	3 / 3	ND - 0.11	2 / 3	ND - 0.0074	2 / 4
Arsenic	T	0.1	0.09	mg/L	0.095 - 0.16	3 / 3	0.14 - 0.56	3 / 3	0.08 - 0.16	3 / 3	0.0027 - 0.12	3 / 3	ND - 0.0075	2 / 4
Azinphos methyl (Guthion)	T	–	–	ug/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Azinphos, methyl (Guthion)	T	–	–	ug/L	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 3
Barium	D	–	0.14	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 0.0014	2 / 3	ND	0 / 4
Barium	T	–	0.21	mg/L	ND - 0.0011	1 / 3	ND - 0.0013	1 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Beryllium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 0.00094	1 / 3	ND	0 / 4
Beryllium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
beta BHC (Beta Hexachlorocyclohexane)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Beta Endosulfan	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Biochemical Oxygen Demand (BOD)	T	–	18	mg/L	120 - 460	3 / 3	170 - 170	3 / 3	150 - 250	3 / 3	19 - 100	3 / 3	12 - 17	4 / 4
Bismuth	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Bismuth	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Boron	D	40	0.14	mg/L	0.28 - 0.47	3 / 3	0.18 - 0.48	3 / 3	0.27 - 0.48	3 / 3	0.16 - 0.48	3 / 3	ND - 0.16	3 / 4
Boron	T	40	0.13	mg/L	0.28 - 0.54	3 / 3	0.27 - 0.58	3 / 3	0.27 - 0.52	3 / 3	0.2 - 0.56	3 / 3	0.12 - 0.2	4 / 4
Bromophos-ethyl	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cadmium	D	0.02	–	mg/L	0.00015 - 0.00037	2 / 3	0.0002 - 0.00030	3 / 3	0.0002 - 0.00030	3 / 3	ND - 0.001	2 / 3	ND	0 / 4
Cadmium	T	0.02	0.0080	mg/L	0.00018 - 0.0002	3 / 3	0.00021 - 0.00018	3 / 3	0.00018 - 0.0003	3 / 3	ND - 0.00003	2 / 3	ND	0 / 4
Calcium	D	–	350	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Carbon disulfide	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cerium	D	–	0.002	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cerium	T	–	0.03	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cesium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 0.0033	1 / 3	ND	0 / 4
Cesium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Chloride (As Cl)	T	260	327	mg/L	260 - 370	3 / 3	240 - 380	3 / 3	260 - 370	3 / 3	11 - 380	3 / 3	1.7 - 4.6	4 / 4
Chlorpyrifos	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Chlorpyrifos Methyl	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Chromium	T	–	0.02	mg/L	0.002	1 / 1	0.0023	1 / 1	0.002	1 / 1	0.0018	1 / 1	ND	0 / 2
Chromium, total	D	–	0.004	mg/L	0.0012 - 0.0014	3 / 3	0.0015 - 0.003	3 / 3	0.0011 - 0.0017	3 / 3	ND - 0.002	2 / 3	ND	0 / 4
Chromium, total	T	–	–	mg/L	0.0013 - 0.0018	2 / 2	0.0013 - 0.002	2 / 2	0.0013 - 0.0014	2 / 2	ND - 0.0033	1 / 2	ND	0 / 2
cis-Chlordane	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cobalt	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cobalt	T	–	0.001	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
COD- Chemical Oxygen Demand	T	–	330	mg O2/L	540 - 1800	3 / 3	810 - 1200	3 / 3	540 - 1200	3 / 3	22 - 1100	3 / 3	ND	0 / 4
Copper	D	20	0.06	mg/L	0.038 - 0.16	3 / 3	0.060 - 0.083	3 / 3	0.014 - 0.09	3 / 3	0.038 - 0.17	3 / 3	ND - 0.044	3 / 4
Copper	T	20	0.09	mg/L	0.0017 - 0.0042	3 / 3	0.0021 - 0.0435	3 / 3	0.0016 - 0.0098	3 / 3	0.0056 - 0.15	3 / 3	0.0012 - 0.022	4 / 4
Coumaphos	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Cyanide	T	–	0.004	mg/L	ND - 3.6	2 / 3	ND - 0.016	1 / 3	ND - 0.47	2 / 3	ND - 0.072	2 / 3	ND - 0.18	3 / 4
delta BHC (Delta Hexachlorocyclohexane)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Diazinon	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Dichlorvos	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Dieldrin	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Dimethoate	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Dinoseb	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Disulfoton	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Dysprosium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Dysprosium	T	–	0.002	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Endosulfan sulfate	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Endrin	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Endrin Ketone	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Erbium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Erbium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Ethion	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Europium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Europium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Fenamiphos (Nemacur)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Fenitrothion	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Fenthion	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Ferrous Iron	T	–	0.14	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Fluoride	T	15	0.41	mg/L	5.6 - 8.6	3 / 3	5.2 - 7.4	3 / 3	6.7 - 8.6	3 / 3	0.16 - 9	3 / 3	ND	0 / 4
Gadolinium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Gadolinium	T	–	0.002	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Gallium	D	–	–	mg/L	0.13 - 0.25	3 / 3	0.14 - 0.26	3 / 3	0.11 - 0.26	3 / 3	0.0056 - 0.21	3 / 3	ND - 0.0013	1 / 4
Gallium	T	–	0.002	mg/L	0.13 - 0.20	3 / 3	0.10 - 0.30	3 / 3	0.10 - 0.31	3 / 3	0.0053 - 0.23	3 / 3	ND - 0.0013	1 / 4
gamma BHC (Lindane)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
gamma-Chlordane	T	–	–	ug/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Germanium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Germanium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Gross alpha particle activity	T	–	0.18	Bq/L	ND - 0.16	1 / 3	0.12 - 0.37	3 / 3	ND - 0.17	2 / 3	ND - 0.078	1 / 3	0.022 - 0.16	2 / 4
Gross beta particle activity	T	–	0.32	Bq/L	ND - 0.35	2 / 3	0.15 - 0.46	3 / 3	ND - 0.36	2 / 3	0.040 - ND	1 / 3	ND - 0.01	1 / 4
Hafnium	D	–	–	mg/L	ND - 0.0014	2 / 3	ND - 0.01	2 / 3	ND - 0.0011	1 / 3	ND - 0.0012	1 / 3	ND	0 / 4
Hafnium	T	–	–	mg/L	ND - 0.0017	2 / 3	0.0025 - 0.011	3 / 3	ND - 0.0013	1 / 3	ND - 0.0015	1 / 3	ND	0 / 4
Hardness (As CaCO3)	D	–	–	mg/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Hardness (As CaCO3)	T	–	–	mg/L	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 3
Heptachlor	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Heptachlor epoxide - isomer a	T	–	–	ug/L	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 3
Heptachlor epoxide - isomer b	T	–	–	ug/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Hexachlorobenzene	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Holmium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Holmium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Indium	D	–	–	mg/L	ND - 0.001	1 / 3	ND - 0.0012	1 / 3	ND - 0.0013	1 / 3	ND - 0.0014	1 / 3	ND	0 / 4
Indium	T	–	–	mg/L	ND - 0.0011	1 / 3	ND - 0.0013	1 / 3	ND - 0.0014	1 / 3	ND - 0.0012	1 / 3	ND	0 / 4
Iron	D	0.3	15	mg/L	ND - 0.018	2 / 3	ND - 0.010	2 / 3	0.012 - 0.014	3 / 3	ND - 0.017	1 / 3	ND	0 / 4
Iron	T	0.3	15.8	mg/L	ND - 0.019	2 / 3	0.015 - 0.085	3 / 3	ND - 0.017	2 / 3	ND - 0.035	1 / 3	ND	0 / 4
Lanthanum	D	–	0.001	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 0.0011	1 / 3	ND	0 / 4
Lanthanum	T	–	0.01	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Lead	D	0.1	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 0.0015	1 / 3	ND	0 / 4
Lead	T	0.1	0.006	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Lithium	D	–	0.003	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Lithium	T	–	0.004	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Lutetium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Lutetium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Magnesium	D	–	40	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Malathion	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Manganese	D	5	0.03	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND - 0.0017	1 / 3	ND	0 / 4
Manganese	T	5	0.12	mg/L	ND	0 / 3	ND - 0.0017	1 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Mercury	D	0.01	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Mercury	T	0.01	0.002	mg/L	0.000054 - ND	1 / 3	0.000061 - ND	1 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Methane	D	–	–	ug/L	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2
Methane	T	–	–	ug/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Methidathion	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Methoxychlor	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Mevinphos	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Mirex	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Molybdenum	D	0.5	0.007	mg/L	2.1 - 3.8	3 / 3	2.0 - 3.8	3 / 3	2.1 - 3.3	3 / 3	0.056 - 3.4	3 / 3	ND - 0.0096	3 / 4
Molybdenum	T	0.5	0.007	mg/L	2.1 - 3.6	3 / 3	2.2 - 3.7	3 / 3	2.1 - 3.4	3 / 3	0.08 - 3.6	3 / 3	ND - 0.0095	3 / 4

EHS Support

Analyte	Fraction	DWER (2021) RPUE	EHS Support Tamala Limestone LIR95	Unit	Clarifier Overflow		Neutralised Feed		Media Filtrate		UF Filtrate		RO Permeate	
					Range	Detect / Sample Count	Range	Detect / Sample Count	Range	Detect / Sample Count	Range	Detect / Sample Count	Range	Detect / Sample Count
Neodymium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Neodymium	T	–	0.008	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
N-Ethyl perfluorooctane sulfonamidoethanol (N-EtFOSE)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
N-ethyl perfluorooctanesulfonamide (N-EtFOSA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
N-Ethyl perfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Nickel	D	0.2	0.002	mg/L	0.0038 - 0.0081	3 / 3	0.0045 - 0.0082	3 / 3	0.0058 - 0.0083	3 / 3	ND - 0.0050	2 / 3	ND	0 / 4
Nickel	T	0.2	0.009	mg/L	0.004 - 0.0064	3 / 3	0.0045 - 0.0067	3 / 3	0.0046 - 0.006	3 / 3	ND - 0.0063	2 / 3	ND	0 / 4
Niobium	D	–	–	mg/L	ND - 0.0012	2 / 3	0.0011 - 0.0048	3 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Niobium	T	–	–	mg/L	ND - 0.0011	1 / 3	ND - 0.0016	1 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Nitrate	T	500	47.4	mg/L	ND	1 / 3	ND - 0.32	1 / 3	ND - 0.78	1 / 3	ND - 0.75	2 / 3	ND - 6.34	3 / 4
Nitrate as N	T	–	10.8	mg/L	0.026 - 0.14	2 / 3	ND - 0.14	2 / 3	ND - 0.18	2 / 3	0.012 - 0.17	3 / 3	0.0004 - 0.076	4 / 4
Nitrate as N + nitrite as N, preserved	T	–	10.8	mg/L	0.078	1 / 1	0.12	1 / 1	0.27	1 / 1	0.21	1 / 1	0.014 - 0.037	2 / 2
Nitrite	T	30	0.77	mg/L	ND	1 / 3	ND - 0.16	2 / 3	ND - 0.32	1 / 3	ND - 0.12	1 / 3	ND	0 / 4
Nitrite as N	T	–	0.23	mg/L	0.047 - 0.096	2 / 3	0.015 - 0.089	2 / 3	ND - 0.096	2 / 3	0.0054 - 0.13	3 / 3	ND	0 / 4
Nitrogen	T	–	11.5	mg/L	7.5	1 / 1	7.1	1 / 1	7.1	1 / 1	6.5	1 / 1	0.01 - 0.70	2 / 2
Nitrogen oxides, NOx	T	–	–	mg/L	0.082 - 0.23	2 / 2	0.025 - 0.13	2 / 2	0.079 - 0.22	2 / 2	0.017 - 0.25	2 / 2	0.014 - 0.037	2 / 2
N-Methyl perfluorooctane sulfonamidoethanol (N-MeFOSE)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
N-methyl perfluorooctanesulfonamide (N-MeFOSA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
N-methyl perfluorooctanesulfonamidoacetic acid (N-MeFOSAA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
N-Nitrosodimethylamine	T	–	–	ug/L	ND	0 / 3	ND - 0.016	1 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
P,P-DDD	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
P,P-DDE	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
P,P-DDT	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Parathion, ethyl	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Parathion, methyl	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Pentachlorophenol	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorobutanesulfonic acid (PFBS)	T	–	–	ug/L	ND - 0.0019	1 / 3	0.0016 - 0.0071	3 / 3	0.0062 - 0.0078	3 / 3	ND - 0.0038	2 / 3	ND	0 / 4
Perfluorobutanoic acid (PFBA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorodecanesulfonic acid (PFDS)	T	–	–	ug/L	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 1	ND	0 / 2
Perfluorododecanesulfonic acid (PFDoS) (free acid)	T	–	–	ug/L	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2
Perfluorodecanoic acid (PFDA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorododecanoic acid (PFDoDA or PFDoA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluoroheptanesulfonic acid (PFHpS)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluoroheptanoic acid (PFHpA)	T	–	–	ug/L	0.00047 - 0.001	3 / 3	0.00078 - 0.0015	3 / 3	0.00088 - 0.0016	3 / 3	ND - 0.0012	2 / 3	ND	0 / 4
Perfluorohexanesulfonic acid (PFHxS)	T	–	–	ug/L	ND - 0.00021	1 / 3	ND - 0.0011	1 / 3	ND - 0.004	2 / 3	ND - 0.0012	1 / 3	ND	0 / 4
Perfluorohexanoic acid (PFHxA)	T	–	–	ug/L	0.0011 - 0.0013	3 / 3	0.00093 - 0.0022	3 / 3	0.0011 - 0.0014	3 / 3	ND - 0.0013	2 / 3	ND - 0.00068	1 / 4
Perfluorononanoic acid (PFNA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorooctanesulfonamide (FOSA or PFOSA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorooctanesulfonic acid (PFOS)	T	–	–	ug/L	ND	0 / 3	ND - 0.00036	1 / 3	ND - 0.00029	1 / 3	ND	0 / 3	ND	0 / 4
Perfluorooctanoic acid (PFOA)	T	–	–	ug/L	0.002 - 0.011	3 / 3	0.01 - 0.03	3 / 3	0.010 - 0.031	3 / 3	ND - 0.011	2 / 3	ND - 0.0019	1 / 4
Perfluoropentane sulfonic acid (PFPeS)	T	–	–	ug/L	ND	0 / 3	ND - 0.0017	1 / 3	0.0014 - 0.0038	3 / 3	ND	0 / 3	ND	0 / 4
Perfluoropentanoic acid (PFPeA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorotetradecanoic acid (PFTeDA or PFTA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluorotridecanoic acid (PFTrDA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Perfluoroundecanoic acid (PFUnDA or PFUnA)	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
pH	T	–	8.1	SU	7.4 - 8.1	3 / 3	7.5 - 8	3 / 3	7.7 - 8.3	3 / 3	6.8 - 8.5	2 / 3	6.2 - 6.8	4 / 4
Phenol	T	–	–	ug/L	1.1 - 6.0	3 / 3	2.5 - 7.5	3 / 3	3.2 - 6.8	3 / 3	3.5 - 6.8	2 / 3	ND - 3.7	3 / 4
Phorate	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Phosalone	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Phosphate as P	T	–	0.08	mg/L	0.026 - 0.0485	3 / 3	0.047 - 0.053	3 / 3	0.028 - 0.051	3 / 3	0.047 - 0.055	1 / 3	ND	0 / 4
Phosphorus	T	–	2.7	mg/L	0.075 - ND	2 / 3	0.34 - 0.58	2 / 3	0.070 - ND	2 / 3	ND	1 / 3	ND	0 / 4
Potassium	D	–	13.1	mg/L	4.8 - 6.8	3 / 3	6.5 - 6.8	3 / 3	6.6 - 6.8	3 / 3	ND - 6.5	2 / 3	ND	0 / 4
Praseodymium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Praseodymium	T	–	0.002	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Rhenium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Rhenium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Ronnel	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Rubidium	D	–	0.01	mg/L	0.0047 - 0.0057	3 / 3	0.0046 - 0.0053	3 / 3	0.0048 - 0.0059	3 / 3	ND - 0.0058	2 / 3	ND	0 / 4
Rubidium	T	–	0.01	mg/L	0.0046 - 0.0084	3 / 3	0.005 - 0.0065	3 / 3	0.0048 - 0.0063	3 / 3	ND - 0.0063	2 / 3	ND	0 / 4
Samarium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Samarium	T	–	0.002	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Scandium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Scandium	T	–	0.001	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Selenium	D	0.1	0.004	mg/L	0.44 - 0.76	3 / 3	0.48 - 0.66	3 / 3	0.43 - 0.64	3 / 3	0.0017 - 0.64	3 / 3	ND - 0.0013	4 / 4
Selenium	T	0.1	0.002	mg/L	0.35 - 0.64	3 / 3	0.30 - 0.60	3 / 3	0.35 - 0.6	3 / 3	0.012 - 0.64	3 / 3	ND - 0.0011	3 / 4
Silicon	D	–	5.4	mg/L	0.63 - ND	1 / 3	0.61 - ND	1 / 3	0.56 - ND	1 / 3	ND	0 / 3	ND	0 / 4
Silicon	T	–	8.8	mg/L	0.63 - ND	2 / 3	0.61 - 1.1	2 / 3	0.58 - ND	2 / 3	ND	1 / 3	ND	0 / 4
Silver	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Silver	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Sodium	D	–	124	mg/L	3700 - 4100	3 / 3	3700 - 4000	3 / 3	3700 - 4000	3 / 3	61 - 4100	3 / 3	1.5 - 38	4 / 4
Strontium	D	–	2.7	mg/L	ND - 0.001	1 / 3	ND - 0.0038	1 / 3	ND - 0.0012	1 / 3	ND - 0.0057	2 / 3	ND	0 / 4
Strontium	T	–	2.7	mg/L	0.0012 - 0.0038	3 / 3	0.0027 - 0.0074	3 / 3	ND - 0.0023	1 / 3	ND - 0.0035	2 / 3	ND - 0.0012	1 / 4
Sulfate (As SO4)	T	1000	660	mg/L	340 - 400	3 / 3	380 - 440	3 / 3	380 - 390	3 / 3	6.5 - 400	3 / 3	ND - 1.9	2 / 4
Sulfide	T	–	–	mg/L	ND	0 / 3	ND - 1.6	1 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Sulfite (As SO3)	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Sulfur	D	–	200	mg/L	79 - 130	3 / 3	79 - 130	3 / 3	74 - 130	3 / 3	0.68 - 130	3 / 3	ND - 0.53	1 / 4
Sulfur	T	–	200	mg/L	79 - 160	3 / 3	97 - 160	3 / 3	99 - 150	3 / 3	0.68 - 160	3 / 3	ND - 0.51	1 / 4
Sum of organochlorine pesticides	T	–	–	ug/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Sum of PFHxS and PFOS	T	–	–	ug/L	ND - 0.00021	1 / 3	ND - 0.0011	2 / 3	ND - 0.004	2 / 3	ND - 0.0012	1 / 3	ND	0 / 4
Sum of positive PFAS values from the reported analytes	T	–	–	ug/L	0.0042 - 0.013	3 / 3	0.014 - 0.031	3 / 3	0.020 - 0.052	3 / 3	ND - 0.018	2 / 3	ND - 0.0016	1 / 5
Sum of US EPA PFAS (PFOS + PFOA)	T	–	–	ug/L	0.001 - 0.011	3 / 3	0.01 - 0.03	3 / 3	0.016 - 0.031	3 / 3	ND - 0.011	2 / 3	ND - 0.0019	1 / 4
Tantalum	D	–	–	mg/L	ND - 0.002	1 / 3	ND - 0.0057	1 / 3	ND - 0.0015	1 / 3	ND	0 / 3	ND	0 / 4
Tantalum	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Tellurium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Tellurium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Terbium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Terbium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Thallium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Thallium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Thiobencarb	T	–	–	mg/L	ND - 2.5	1 / 3	ND - 1.2	1 / 3	ND - 2	1 / 3	ND	0 / 3	ND	0 / 4
Thorium	D	–	0.002	mg/L	ND - 0.0024	2 / 3	0.0012 - 0.0033	3 / 3	0.00061 - 0.0015	3 / 3	ND - 0.001	2 / 3	ND	0 / 4
Thorium	T	–	0.003	mg/L	0.00094 - 0.0027	3 / 3	0.00082 - 0.003	3 / 3	ND - 0.001	2 / 3	ND - 0.00062	2 / 3	ND	0 / 4
Thulium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Thulium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Tin	D	–	0.001	mg/L	ND - 0.0012	2 / 3	ND - 0.0012	3 / 3	ND - 0.0014	1 / 3	ND - 0.0014	2 / 3	ND	0 / 4
Tin	T	–	0.002	mg/L	ND - 0.0019	2 / 3	ND - 0.0038	2 / 3	ND - 0.0012	1 / 3	ND - 0.001	1 / 3	ND	0 / 4
Titanium	D	–	–	mg/L	0.002 - 0.0054	3 / 3	0.0013 - 0.0076	3 / 3	0.0028 - 0.0063	3 / 3	ND - 0.0055	2 / 3	ND	0 / 4
Titanium	T	–	0.07	mg/L	0.0029 - 0.0064	3 / 3	0.0018 - 0.0053	3 / 3	0.0028 - 0.0064	3 / 3	ND - 0.0052	2 / 3	ND	0 / 4
Total Carbon	T	–	–	mg/L	1500 - 2200	3 / 3	1500 - 2300	3 / 3	1500 - 2200	3 / 3	61 - 2200	3 / 3	2.5 - 25	4 / 4
Total Dissolved Solids (Residue, Filterable)	T	–	1068	mg/L	6400 - 11000	3 / 3	6700 - 11000	3 / 3	6400 - 11000	3 / 3	390 - 11000	3 / 3	7 - 120	4 / 4
Total Inorganic Carbon	T	–	–	mg/L	1200 - 1700	3 / 3	1200 - 1800	3 / 3	1200 - 1800	3 / 3	54 - 1800	3 / 3	ND - 24	3 / 4
Total Kjeldahl Nitrogen	T	–	1.1	mg/L	4.2 - 16	2 / 2	4.1 - 10	2 / 2	4.1 - 11	2 / 2	1 - 13	2 / 2	0.70 - 1.5	2 / 2
Total Kjeldahl Nitrogen as N	T	–	–	mg/L	7.4	1 / 1	6.8	1 / 1	7	1 / 1	6.2	1 / 1	0.6 - 0.69	2 / 2
Total Nitrogen, All Forms, Calculated	T	–	–	mg/L	4.2 - 16	2 / 2	4.2 - 10	2 / 2	4.2 - 11	2 / 2	1 - 13	2 / 2	0.01 - 1.5	2 / 2
Total Organic Carbon	T	–	18	mg/L	240 - 600	3 / 3	250 - 580	3 / 3	240 - 540	3 / 3	10 - 590	3 / 3	1.4 - 3.8	4 / 4
Total Suspended Solids	T	–	488	mg/L	16 - 78	3 / 3	130 - 3000	3 / 3	16 - 66	3 / 3	ND - 11	1 / 3	ND	0 / 4
trans-Chlordane	T	–	–	ug/L	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2	ND	0 / 2
Tungsten	D	–	1.4	mg/L	0.57 - 0.67	3 / 3	0.53 - 0.1	3 / 3	0.54 - 3.2	3 / 3	0.37 - 0.71	2 / 3	ND - 1	3 / 4
Tungsten	T	–	0.02	mg/L	0.13 - 0.21	3 / 3	0.12 - 0.21	3 / 3	0.12 - 0.2	3 / 3	ND - 0.21	2 / 3	ND	0 / 4
Uranium	D	0.017	–	mg/L	0.01 - 0.001	3 / 3	0.012 - 0.024	3 / 3	0.0099 - 0.028	3 / 3	ND - 0.023	2 / 3	ND	0 / 4
Uranium	T	0.017	0.001	mg/L	0.01 - 0.025	3 / 3	0.012 - 0.026	3 / 3	0.01 - 0.023	3 / 3	ND - 0.024	2 / 3	ND	0 / 4
Vanadium	D	–	0.005	mg/L	3.3 - 4.2	3 / 3	3.5 - 4.4	3 / 3	3.2 - 4.1	3 / 3	0.018 - 4.3	3 / 3	ND - 0.012	3 / 4
Vanadium	T	–	0.01	mg/L	3.6 - 4.7	3 / 3	3.4 - 4.9	3 / 3	3.2 - 4.3	3 / 3	0.087 - 4.8	3 / 3	ND - 0.011	3 / 4
Ytterbium	D	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Ytterbium	T	–	–	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Yttrium	D	–	0.002	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Yttrium	T	–	0.01	mg/L	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 3	ND	0 / 4
Zinc	D	3	0.04	mg/L	0.0011 - 0.0074	3 / 3	ND - 0.0044	2 / 3	0.0033 - 0.0054	3 / 3	0.0013 - 0.0022	3 / 3	ND - 0.0017	2 / 4
Zinc	T	8	0.02	mg/L	0.0026 - 0.012	3 / 3	0.0024 - 0.0067	3 / 3	0.0014 - 0.0088	3 / 3	0.0067 - 0.016	3 / 3	ND - 0.0044	2 / 4
Zirconium	D	–	–	mg/L	0.0058 - 0.011	3 / 3	0.0081 - 0.025	3 / 3	ND - 0.006	1 / 3	ND - 0.0052	1 / 3	ND	0 / 4
Zirconium	T	–	–	mg/L	0.0051 - 0.042	3 / 3	0.0052 - 0.013	3 / 3	ND - 0.012	1 / 3	ND - 0.0073	1 / 3	ND	0 / 4

Appendix C Predicted Groundwater Mounding Figures



Internal Document Control Information:
User Name: Chathuri.Nisansala Date and Time Printed: 11/4/2025 6:40 PM Document Path: Y:\GIS_Projects\Alcoa\Kwinana\20250820_ARMP\Figures\03_Mapping\MonitoringBoreNetwork.aprx

Groundwater Mounding

0 0.25 0.5 1 1.5 2 km

[Page Size: A3]

LEGEND

Waterways

LSD series

TPD series

Mounding Contours

Commissioning Monitoring and Management Plan

EHS Support

Perth

N

Appendix C

CREATED BY:	C. Nisansala
APPROVED BY:	C. Smith
PROJECT REF. NO:	PTY.06099
MAP PROJECTION:	Transverse Mercator
GRID/DATUM:	GDA2020 MGA Zone 50
SCALE:	1:22,219
AERIAL IMAGE SOURCE:	ESRI Basemap

Appendix D Revised and Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification for Low Reliability Values of Select Metals – Technical Memorandum

EHS Support

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Technical Memorandum

To: [redacted]

From:

CC:

Date: 30 July 2025

Re: Revised Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound - EQG Identification and Derivation for Low Reliability Values of Select Metals

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Executive Summary

EHS Support PTY ("EHS Support") was engaged by Alcoa of Australia Limited ("Alcoa") to contemporise environmental quality guidelines (EQGs) values that could be adopted for Cockburn Sound which is adjacent to the Alcoa Kwinana Refinery located on Hogg Road, Naval Base, Western Australia 6165 (Lot 102 on Parcel 18242, "Refinery" or "Site"). Previous investigations indicate the likelihood of unacceptable risk to the ecology of Cockburn Sound seems Low. However, in some of these investigations low reliability values (LRVs) have been adopted or guideline values were absent for some constituents of potential ecological concern (COPECs). By establishing higher reliability values, the assessment to ecological receptors in Cockburn Sound can be evaluated with increased certainty.

Significant work has been undertaken at the Site, including annual reviews of groundwater, detailed investigations and focused remediation to understand the extent of impacts and to mitigate unacceptable risks. A Preliminary Site Investigation (PSI) was undertaken in 2014 by Golder Associates Pty Ltd ("Golder") which is the first step in the contaminated sites assessment process. Concurrently, a preliminary Conceptual Site Model (CSM) for the Refinery was developed based on the information from the PSI. As a result of the PSI and CSM there was an increased focus to undertake assessments along the western boundary adjacent to Cockburn Sound rather than the wider PSI study area.

A Mandatory Auditor's Report (MAR) was prepared by Jeremy Hogben, an accredited contaminated site Auditor, in 2018 (Senversa, 2018). The MAR was prepared to fulfill requirements under the *Contaminated Sites Act 2003* as a result of adjacent boundary Lots being classified in 2017, which lead to the Refinery being considered as a Source Site. In total, six reported parcels adjacent to the western boundary have been classified as possibly contaminated – investigation required (PC-IR). As discussed in

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the MAR and Golder (2017), Site metals with concentrations exceeding Tier 1 ecological criteria are as follows:

- Aluminium, gallium, iron, manganese and molybdenum exceed low reliability values (LRVs);
- Arsenic and selenium exceed other overseas guidelines; and,
- Chromium (III), vanadium and zinc exceed moderate protection EQGs.

The Auditor noted in review of the consultant's conclusions that "based on the overall weight of evidence collected to date (including the ecological surveys conducted by Oceanica) the likelihood that identified potential impacts are, or have the potential to, result in a measurable and unacceptable risk to the ecology of Cockburn Sound seems low." The MAR concluded that there "appears to be no unacceptable risk to human health associated with identified groundwater impacts and concurred with the consultant's conclusion that identified impacts represent a potential risk to ecological receptors and that this risk has not been confidently assessed to date." As such, the recommendation was made that additional assessments were needed to adequately characterise the relevant groundwater conditions and draw more robust risk-based conclusions for the Site as noted in the classification letter from DWER received 30 June 2023. Clearly defining relevant and applicable criteria for the marine environment is fundamental to the assessment of ecological risk and evaluation of risk management requirements in accordance with this request.

A review of the current management framework for Cockburn Sound and available water quality criteria guidance is summarised below along with recommendations for refined metal EQGs.

The *State Environment Policy (SEP) for Cockburn Sound* was updated in 2015 and outlines an environmental quality management framework for the water body. "The overall objective of the [SEP] is to ensure that water quality of the Sound is maintained and where possible improved so that there is no further net loss and preferably a net gain in seagrass areas, and that the other values and uses are maintained." Areas of high, moderate and low ecological protection are established spatially to maintain the objective of overall ecosystem ecological integrity while accommodating historical and current land use activities. The high, moderate, and low ecological protection EQGs are based on the 99th, 90th, and 80th percent species protection levels, respectively. The shoreline adjacent to the Refinery is designated as moderate ecological protection, with an area of low ecological protection to the south associated with a neighbouring industrial area.

The *Environmental Quality Criteria (EQC) Reference Document for Cockburn Sound* ("*EQC Reference Document*") defines numerical and narrative EQGs and environmental quality standards (EQSs). EQGs are "threshold numerical values, or narrative statements, which if met indicate there is a high degree of certainty that the associated environmental quality objective has been achieved", while EQSs indicate "a level beyond which there is a significant risk that the associated environmental quality objective has not been achieved and a management response is triggered". However, several of the numeric limits available for analytes of interest within and adjacent to the Site are considered "low reliability". LRVs are designated as such because they are derived from insufficient toxicity data to be defined as an EQG. The LRVs in the *EQC Reference Document* were developed based on the toxicity data available when the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ) guidance was adopted in 2000 – with many LRVs based on toxicological literature from over 20 years prior to guidance publication. The updated guidance, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018), states that LRVs should only be used in the following circumstances:

- in the interim;
- with a plan to improve the value;
- with other lines of evidence to account for the low reliability and improve the overall confidence in the assessment; and,
- with documented justification for why the LRV is used.

LRVs are derived by a variety of methods including:

- adopting values from freshwater toxicity data;
- adopting from international jurisdictions;
- using background data; or
- through the assessment factor method.

The assessment factor method is the most employed approach used to derive LRVs. This approach uses an arbitrary "assessment factor" or an empirically derived acute-to-chronic ratio (ACR) to convert the most sensitive acute effect concentration from the literature to a conservative value that serves as a proxy for chronic effects. The LRVs for aluminium, arsenic, gallium, manganese, selenium and molybdenum were all determined by the lowest available toxicity value using the assessment factor method. The marine gallium LRV is based on freshwater data rather than marine data. The iron LRV is adopted from Canadian freshwater guidelines. The arsenic and selenium overseas guidelines are also based on an assessment factor method and derived by the United States Environmental Protection Agency (USEPA) in 1984 and 1987, respectively. Despite advances in the approach to formally derive EQGs and numerous additional ecotoxicological studies assessing marine metals, few LRVs have been updated since ANZECC & ARMCANZ (2000).

The *EQC Reference Document* details an approach to develop EQGs or upgrade LRVs to EQGs (based on the guidance available at the time in ANZECC & ARMCANZ (2000) and ANZG (2018)). *EQC Reference Document*, ANZG (2018) and Warne et al. (2018) outline a framework to establish EQGs utilising a more technically robust species sensitivity distribution (SSD) method. The SSD method consists of collation of toxicological literature, an assessment of its quality, detailed methods for identification of a single toxicity value per species and distribution fitting using shinyssdtools ("ssdtools") software (Thorley et al., 2025) to calculate values at different levels of protection, with the end result of deriving risk-based limits for aquatic receptors. SSD approaches are favourable because they consider all available toxicity data rather than only using the most sensitive toxicity data point, allowing for statistical confidence intervals to be calculated and enabling estimation of specific levels of protection from the fitted cumulative probability distribution function. SSD-derivation methods form the basis of the EQGs in the *EQC Reference Document* and are considered default guideline values in ANZG (2018). These values can also be updated to reflect site-specific conditions or new scientific information.

This memo is a revision of the *Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound - EQG Identification and Derivation for Low Reliability Values of Select Metals Memo* dated 26 March 2024 ("2024 Derivation Memo"; EHS Support, 2024). This revised memo was prepared in response to the comment letters received from the Auditor and the Auditor's Supporting Expert Team ("SET") on 21 January 2025 and 28 January 2025 regarding the 2024 Derivation Memo. The comments received focused on the methodological approach to the derivation of EQGs for specific analytes with LRVs. When the 2024 Derivation Memo was drafted, Burrlioz 2.0 (CSIRO, n.d.) was the recommended software for deriving species protection levels using SSDs under ANZECC & ARMCANZ (2000). The SET requested that the latest statistical tool approved for use by ANZG and the National Water Quality Management Strategy (NWQMS) governing committee, ssdtools (Thorley et al., 2025), be used to revise EQGs as it will be the recommended software for calculating SSDs for criteria derivation moving forward. As an alternative to the Burrlioz 2.0 approach of selecting a single distribution to develop an SSD, ssdtools incorporates numerous statistical distributions through model-averaging, providing the ability to reliably fit statistical distributions to a broader range of input data structures and, therefore, providing more statistically robust estimates of species protection. Based on the SET recommendations, updated EQGs have been developed for specific analytes using the latest version of ssdtools (v2.2.0) and results are reported herein.

This revised memo is focused on aluminium, arsenic, gallium, iron, manganese, molybdenum and selenium as these COPECs were identified based on comparison of groundwater concentrations to LRVs or overseas guidelines.

Searches of the available ecotoxicological literature limits found that aluminium (van Dam et al., 2018), arsenic (Golding et al., 2022), gallium (van Dam et al., 2018), manganese (Golding et al., 2023) and molybdenum (van Dam et al., 2018) had published criteria that were derived in accordance with ANZG (2018) and are suitable to be used as EQGs. However, these publications employed Burrlioz 2.0 software and/or previous versions of ssdtools (<v2.2.0) to derive their criteria. Therefore, consistent with the SET recommendations, the input datasets from these publications were re-evaluated using the ssdtools v2.2.0 methodology to produce updated EQGs. It is noted that there are draft marine DGVs under consideration by ANZG for several of these metals (gallium, molybdenum and manganese). If these draft DGVs become finalised, they will be adopted as the EQGs for Cockburn Sound. However, in the interim, EQGs identified through an assessment of contemporised data from available ecotoxicological literature using the latest SSD methodology will be implemented.

ANZG recently published finalised marine DGVs for aluminium (ANZG, 2025) that expressly build upon the work of van Dam et al. (2018). The finalised DGVs for aluminium allow for the assessment of high (9 µg/L), moderate (72 µg/L) and low (160 µg/L) ecological protection within Cockburn Sound. However, these finalised DGVs contain underlying technical deficiencies that preclude their adoption as EQGs for Cockburn Sound. The noted technical deficiencies include the use of Burrlioz 2.0 software to derive the ANZG (2025) criteria. Therefore, consistent with the SET recommendations, the toxicity data collated for ANZG (2025) was evaluated with ssdtools v2.2.0 to produce updated EQGs for aluminium. The updated EQGs for the assessment of high (9.2 µg/L), moderate (86 µg/L) and low (190 µg/L) ecological protection within Cockburn Sound show close alignment to those in ANZG (2025). Considering the technical deficiencies in ANZG (2025) that have been identified, the updated EQGs derived using ssdtools v2.2.0 are preferred for implementation in Site monitoring efforts. The ANZG (2025) aluminium values will also be considered for screening purposes while additional review of the technical deficiencies is conducted by the Audit Team. Further discussions with the Audit Team are warranted to review relevant and applicable datasets needed to derive more refined site-specific Tier 3 criteria.

No commensurate literature-sourced limits were identified for selenium in the marine environment; thus, derivation was required. Contemporised data for marine selenium ecotoxicity was collated and analysed using the SSD method to derive a moderate reliability EQG. The current LRV for selenium is 3 µg/L and is based on a single effect concentration estimated using nominal concentration data (Nelson et al., 1988). The overseas guideline for selenium (IV) of 71 µg/L is based on the conversion of a final acute value to a chronic value using an ACR. Both the selenium LRV and the overseas guideline do not enable precise quantification at specific levels of ecosystem protection. In total, eight studies were reviewed and considered in the derivation process. The SSD-derived EQGs reported herein considered effects data from 20 species across six taxonomic groups. The derived selenium EQGs allow for the assessment of areas of high (9.3 µg/L), moderate (31 µg/L) and low (76 µg/L) ecological protection within Cockburn Sound. Since selenium is known to bioaccumulate in the aquatic environment, the high, moderate and low ecological protection EQGs were based on the 99th, 95th and 85th percentiles in the cumulative probability distribution, respectively. To establish greater confidence in the protectiveness of the EQGs for selenium, an additional lines-of-evidence assessment was conducted to directly consider the bioaccumulation pathway in Cockburn Sound (**Attachment E**). There are acknowledged uncertainties associated with this lines-of-evidence assessment, specifically regarding parameterisation of the quantitative dietary model, that preclude the adoption of the selenium EQGs derived for Site monitoring efforts at this time. Additional model refinement through the collection of site-specific parameters is recommended to reduce these uncertainties and develop a reliable EQG that is protective of receptors in Cockburn Sound. Until refinement occurs, the 95th percentile background concentration of 10 µg/L will be adopted as the interim selenium EQG for the purpose of advancing the program.

The iron LRV was refined based on recent freshwater guidelines because no suitable marine toxicity dataset was identified. Iron toxicity data collated by Environment and Climate Change Canada (ECCC) includes normalised effects concentrations from 27 freshwater species (ECCC, 2024). Normalisation of effects concentrations relies upon species-specific multiple linear regression (MLR) models to calculate effects concentrations for different taxonomic groups (Brix et al., 2023). The MLR models account for system-specific pH and dissolved organic carbon (DOC) concentrations, which can serve as toxicity-modifying factors (TMFs) for iron. To calculate EQGs for Cockburn Sound, contemporised toxicity data were normalised to the median-case background water scenario (pH = 8.2 s.u., DOC = 1.1 mg/L) and the resulting values were then processed using ssdtools v2.2.0. The derived iron EQGs allow for the assessment of areas of high (36 µg/L), moderate (300 µg/L) and low (590 µg/L) ecological protection within Cockburn Sound. For the purpose of advancing the program, these values represent the interim EQGs for iron. However, given that water quality directly influences iron toxicity and that the input data are based on toxicity in freshwater systems, further evaluation could be required to develop a reliable set of EQGs that are protective of receptors in Cockburn Sound. The absence of robust toxicological effect data in the marine environment still presents a data gap.

In addition to the identification or derivation of suitable EQGs, a comprehensive evaluation of available background surface water data was conducted for areas of Cockburn Sound situated north and south of the Refinery. In total, 49 samples were included in the assessment, which were obtained during field investigations conducted in 2001, 2006, 2011 and 2023. Data obtained for samples analysed for aluminium, arsenic, chromium, gallium, iron, lead, manganese, mercury, molybdenum, selenium, uranium and vanadium were used to establish 95th percentile background concentrations. The 95th percentile is suitable for comparison of areas of moderate level of ecological protection as stipulated by the *EQC Reference Document*. Although the understanding of background concentrations has been refined substantially from the current evaluation, additional data gaps in metals analysed and fractions sampled were identified. Considerations with respect to addressing these data gaps in background sampling are provided below.

The contemporised EQGs compiled herein are appropriate for the assessment of routine monitoring data collected adjacent to the Refinery in Cockburn Sound. As per the *EQC Reference Document for Cockburn Sound*, "the extent of the area from which environmental quality data are to be collected and compared against the EQC will depend on the objective of the monitoring and reporting program and will therefore need to be established on a case-by-case basis and clearly defined in the monitoring program." The dynamic intertidal environment present adjacent to the Refinery should be considered in any evaluation focused on assessing the maintenance of ecosystem integrity environmental quality objective. It is recommended that any routine monitoring data collected be obtained in a manner that reduces uncertainty associated with the spatially and temporally heterogeneous coastal setting associated with tides.

To address spatial considerations, field sample collection should be carried out in a grid or transect-based approach with sufficient data density to calculate defensible upper confidence limits (UCL) of the mean (e.g., 95^{th} percent UCL_{Mean}) as well as distribution statistics (e.g., median, 95^{th} percentiles) across a pre-defined exposure area of interest. The 95^{th} percent UCL_{mean} is conservative assessment used to assess average exposure conditions to an aquatic receptor, whereas the 95^{th} percentile can be used to assess exposure conditions to an individual receptor under extreme exposure conditions. Multiple sampling events using the same sampling station configuration should be employed to address potential for seasonal and/or tidal variability present. An effective approach to understand the role of tides and tidal mixing on conditions in Cockburn Sound is to conduct hourly sampling at a fixed point in space. Once an understanding of the range of exposure conditions present due to tidal interaction is understood, a more comprehensive monitoring program can be developed. Typically, periods occurring immediately after low tide represent the 'worst-case' scenario for exposure when evaluating the effect of groundwater sources on tidal receiving water bodies. Once an understanding of exposure conditions is established, refinement to the sampling program can be made to adequately assess conditions most representative of chronic or acute exposure durations. These approaches can include time-weighted averaging to integrate conditions across the exposure duration of interest (i.e., acute or chronic).

Media assessed as part of any routine monitoring program in Cockburn Sound should be focused on the aqueous phase given the nature of the substrate present adjacent to the Site and the disparity in derivation methodology between aqueous phase and solid phase criteria under the ANZG (2018). Monitoring programs should consider surface water samples collected at the sediment-surface water interface and sediment pore water using co-located sampling approaches. Samples should be obtained for unfiltered and filtered fractions to refine understanding of metal distribution across the aqueous matrix. The coarse sand substrate present within the intertidal environment is not fine-grained depositional sediment. Therefore, bulk media concentrations would not provide suitable information to compare with existing sediment quality guideline values and are not recommended. In addition, the approach employed under ANZG (2018) to derive the sediment values is not directly comparable to the approach used to derive water quality guidelines, so conclusions reached through one matrix are not directly comparable to the other. Detailed approaches will be provided as part of a forthcoming Sampling, Analytical and Quality Plan (SAQP).

In summary, this work provides a critical review of relevant and applicable EQGs to aid in the assessment of ecological conditions to aquatic, pelagic and sediment-dwelling organisms in Cockburn Sound. The approach used a combination of ANZG (2018) limits, *EQC Reference Document for Cockburn Sound* and contemporised guidelines both derived herein and published in the elsewhere in the literature.

Introduction

EHS Support PTY ("EHS Support") was engaged by Alcoa of Australia Limited ("Alcoa") to contemporise environmental quality guidelines (EQGs) values that could be adopted for Cockburn Sound which is adjacent to the Alcoa Kwinana Refinery located on Hogg Road, Naval Base, Western Australia 6165 (Lot 102 on Parcel 18242, "Refinery" or "Site"). Previous investigations indicate the likelihood of unacceptable risk to the ecology of Cockburn Sound seems low. However, in some of these investigations low reliability values (LRVs) have been adopted or had no guidelines values for some of constituents of potential ecological concern (COPEC). By establishing higher reliability values, the assessment to ecological receptors in Cockburn Sound can be evaluated with increased certainty. Lot 102 is bound to the east by the railroad tracks that parallel Cockburn Road and by multiple beach parcels adjacent to Cockburn Sound to the west (**Figure 1**).

The Refinery produces alumina (AlO_2) from bauxite ore using the Bayer process and has been operational since 1963. It is understood that historical operations resulted in the underlying groundwater below the Refinery to become impacted due to the absence of hard stand surfaces which was rectified in the 1980s. Key chemical indicators that typically characterise groundwater impacts from the Refinery process include the alkaline salts caustic soda (NaOH) and sodium carbonate (Na_2CO_3), elevated pH, increased alkalinity and salinity, although this indicator can be misleading near the coast. Significant work has been undertaken at the Site, including annual reviews of groundwater, specific investigations and focused remediation to understand the extent of impacts and mitigate unacceptable risks. A Preliminary Site Investigation (PSI) was undertaken by Golder Associates Pty Ltd ("Golder") which is the first step in the contaminated sites assessment process (2014a). Concurrently, a preliminary Conceptual Site Model (CSM) for the Refinery was developed based on the information from the PSI (2014b).

As a result of the PSI and CSM (Golder, 2014a and 2014b) there was an increased focus to understand the hydrogeological regime and potential risks from the western boundary. Through the additional investigations focusing on the western boundary the CSM was refined. It was recommended that three land parcels (Lots 171, 227 and 228) be reported to the Department of Water and Environmental Regulation (DWER) as possibly contaminated – investigation required (PC-IR). The land parcels were reported due to the presence of the underlying groundwater containing metal concentrations exceeding the adopted assessment criteria at that time.

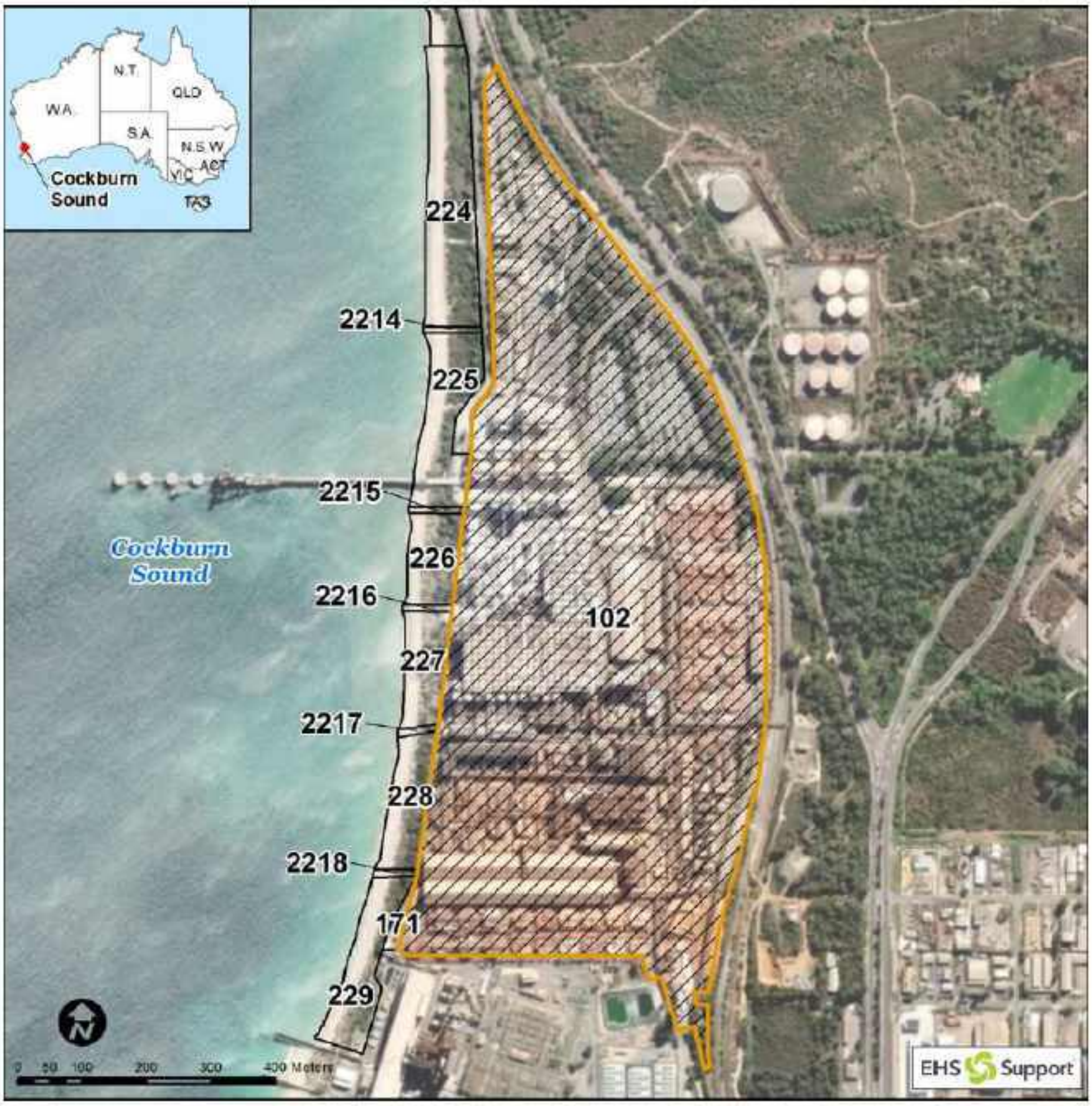


FIGURE 1 **SITE VICINITY MAP ILLUSTRATING PARCEL 102 OF THE ALCOA KWINANA ALUMINA REFINERY AND ADJACENT BEACH PARCELS**

Jeremy Hogben as an accredited contaminated sites Auditor prepared a Mandatory Auditor's Report (MAR; Senversa, 2018) in 2018 given Lot 102 was considered as a source Site. The MAR recommend that an additional land parcel (Lot 2217) be reported to DWER. Two additional land parcels (Lots 229 and 2218) were reported to DWER following additional monitoring and assessment. In total, six reported parcels were classified as PC-IR. The MAR broadly concluded that there appeared to be no unacceptable risk to human health associated with groundwater, however the risk to ecological receptors could not be confidently assessed (Senversa, 2018). As such, the Golder report (2017) and the MAR recommended that additional assessments were needed to adequately characterise the relevant groundwater conditions and draw more robust risk-based conclusions for the Site.

The Golder (2014), Golder (2017) and Golder (2022) reports assessed groundwater data for potential adverse effects to both human health and ecological receptors. The screening criteria used to assess the risk associated with toxicants varied in each report based on the criteria available at the time. Golder (2014) screened data against Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ, 2000) marine criteria, domestic non-potable water use criteria and National Environmental Protection Measure (NEPM) 2013 Groundwater Investigation Levels (GILs) for Marine waters. Golder (2017) screened Site groundwater against ANZECC & ARMCANZ (2000) low reliability trigger values. The Golder (2022) human health assessment screened groundwater data against environmental quality criteria for the maintenance of primary contact recreation from the *Environmental Quality Criteria (EQC) Reference Document for Cockburn Sound* ("*EQC Reference Document*"; Western Australia Environmental Protection Agency (WA EPA), 2017), Western Australia Department of Health Non-Potable Use Guidelines (DWER, 2014) and Site-Specific Human Health Risk Assessment criteria. The Golder (2022) ecological assessment screened groundwater data against the moderate protection environmental quality criteria from the *EQC Reference Document*, Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG; 2018) marine ecosystems criteria and select United States Environmental Protection Agency (USEPA) marine ecological guidelines, some of which are considered low reliability values (LRVs) as part of the *EQC Reference Document*.

The MAR noted that several existing exceedances of ecological criteria were attributed to metals with LRVs. LRVs had insufficient information on toxicity at the time of development of the ANZECC and ARMCANZ guidance in 2000 to be adopted as EQG in the *EQC Reference Document*. LRVs are not recommended for assessing environmental performance, but they do provide managers with information that can assist with decision-making regarding environmental quality in Cockburn Sound.

Advancements in the water quality guidelines utilised in the screening assessment including updates to previously established EQG or development of EQG specific to Western Australia have occurred between Golder (2014) and Golder (2022). In addition, some metals detected in groundwater were not screened against available ecological criteria as part of Golder (2014) and Golder (2022). Therefore, clearly defining relevant and applicable criteria for the marine environment is fundamental to the assessment of ecological conditions in Cockburn Sound. Site metals with concentrations exceeding Tier 1 ecological criteria are as follows:

- Aluminium, gallium, iron, manganese and molybdenum exceed LRVs;
- Arsenic and selenium exceed other overseas guidelines; and,
- Chromium (III), vanadium and zinc exceed moderate protection EQGs.

This assessment is focused on aluminium, arsenic, gallium, iron, manganese, molybdenum and selenium as these COPECs are based on comparison of groundwater concentration to LRVs or overseas guidelines.

Objectives

The overarching objective of this technical memorandum is to contemporise EQGs for Cockburn Sound adjacent to the Refinery to provide more confidence in ecological assessment of aqueous media.

Specifically, this assessment is informed by the following technical objectives:

- Review the spatial extent of ecological protection areas in the vicinity of the Site as established by the *State Environmental (Cockburn Sound) Policy* (SEP; Government of Western Australia, 2015) to ensure the appropriate ecological protection area.
- Assess the technical basis for existing EQGs defined by the *EQC Reference Document* (WA EPA, 2017).
- Summarise acceptable approaches to derive or update EQGs described in the SEP or EQC *Reference Document* and other applicable Australian guidance including:
  - ANZECC and ARMCANZ (2000)
  - ANZG (2018)
- Conduct a critical review of the derivation process for LRVs for Site metals of interest (aluminium, arsenic, gallium, iron, manganese, molybdenum and selenium) and determine if sufficient contemporary information exists to establish EQGs.
- Identify suitable EQGs or derive EQGs for select LRV metals in accordance with ANZG (2018) for consideration in future assessments.
- Assess available background marine water data for Cockburn Sound, which can be used to understand marine conditions in the absence of available toxicological data to inform EQG derivation.
- Describe how site-specific EQGs should be applied within Cockburn Sound per the SEP and *EQC Reference Document* and what measurement approaches would best be employed to assess conditions at the point of exposure to ecological receptors.

Document Structure

This document is structured as follows:

- **Regulatory Background** – briefly summarises the Site in the context of the regulatory framework for monitoring water quality in Cockburn Sound.
- **Critical Review of Low Reliability Values** – describes the LRVs of interest at the Site, derivation process and provides a review of contemporised alternatives to LRVs.
- **EQGs Identified or Derived for Select Metal LRVs** – describes the approach to identify and derive EQGs for select LRV metals.
- **Assessment of Background Conditions in Cockburn Sound** – describes the assessment process of available background data and current data gaps.
- **Application of Contemporised Guidelines** – summarises the contemporised EQGs and describes the framework of implementation.
- **Conclusions** – summarises the key findings and implications for future analyses.

Attachments included with this document are as follows:

- **Attachment A** – Detailed Technical Basis for Low Reliability Values

- **Attachment B** – Background Marine Dataset
- **Attachment C** – Selenium Environmental Quality Guideline Derivation
- **Attachment D** – Assessment of Available Tissue Data
- **Attachment E** – Selenium Dietary Exposure Model for Cockburn Sound

Regulatory Background

The objectives of the regulatory background review are to:

- Understand the spatial extent of ecological protection areas in the vicinity of the Site as established by the SEP;
- Assess the technical basis for existing EQGs defined by the *EQC Reference Document*; and,
- Summarise acceptable approaches to derive or update EQGs described in the SEP, *EQC Reference Document* and other applicable Australian guidance documents.

Levels of Ecological Protection Defined by the SEP

The SEP for Cockburn Sound was updated in 2015 and outlines an environmental quality management framework for the water body. The SEP states *"the overall objective of the Policy is to ensure that water quality of the Sound is maintained and where possible improved so that there is no further net loss and preferably a net gain in seagrass areas and that the other values and uses are maintained* (Government of Western Australia, 2015)." Objectives of the SEP are broken down by environmental values as follows:

- Ecosystem health;
- Fishing and aquaculture;
- Recreation and aesthetics;
- Cultural and spiritual values; and,
- Industrial water supply.

The environmental quality objective for ecosystem health is "*maintenance of ecosystem integrity*", where ecosystem integrity is considered in terms of ecosystem structure and function.

Three different levels of ecological protection are outlined to meet these objectives and are established spatially to maintain the objective of overall ecosystem ecological integrity while accommodating historical and current land use activities. **Figure 2** illustrates the spatial distribution of areas of low, moderate and high levels of ecological protection defined by the SEP. The description of the different levels is below:

- A high level of ecological protection "means to allow small changes in the quality of water, sediment or biota (i.e., small changes in contaminant concentrations with no resultant detectable changes beyond natural variation in the diversity of species and biological communities, ecosystem processes and abundance/biomass of marine life)".
- A moderate level of ecological protection "means to allow moderate changes in the quality of water, sediment and biota (i.e., moderate changes in contaminant concentrations that could cause small changes beyond natural variation in ecosystem processes and abundance/biomass of marine life, but no detectable changes from the natural diversity of species and biological communities)."

- A low level of ecological protection "means to allow for large changes in the quality of water, sediment and biota (i.e., large changes in contaminant concentrations that could cause significant changes beyond natural variation in the natural diversity of species and biological communities, rates of ecosystem processes and abundance/biomass of marine life, but which do not result in bioaccumulation/biomagnification in nearby High ecological protection areas)."

A moderate ecological protection level predominately exists in Cockburn Sound adjacent to the Refinery, whereas a low ecological protection level exists adjacent to the southernmost portion associated with a neighbouring industrial area (**Figure 2**). The ongoing shipping and dredging maintenance activities at the Alcoa Jetty likely warrants designation of the area around this feature as a low ecological protection area.

FIGURE 2 **COCKBURN SOUND LEVELS OF ECOLOGICAL PROTECTION SPECIFIED BY THE SEP**

Technical Basis for Existing EQGs Defined by the EQC Reference Document

The WA EPA established an environmental quality management framework for Cockburn Sound, which was given effect through the SEP. Revised in 2017, the framework is underpinned by established environmental values and clearly expressed and spatially defined environmental quality objectives to guide decision-making and provide management goals. The *EQC Reference Document* is predominantly based on the guidelines and approaches recommended in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000).

The levels of environmental protection outlined were developed in accordance with the levels of protection outlined by ANZECC & ARMCANZ (2000). The spatial locations in Cockburn Sound designated as high, moderate and low levels of protection illustrated in **Figure 2** align with the ANZECC & ARMCANZ (2000) "trigger values" targeting 99th percent, 90th percent and 80th percent species protection levels, respectively. *EQC Reference Document for Cockburn Sound* recommends adopting consistent methodology for developing EQGs for all moderate ecological protection areas; however, it notes that "it may be appropriate to monitor a subset of indicators for some marinas and harbours depending on potential threats to environmental quality and the benthic habitats."

At the time development of the *EQC Reference Document*, mechanisms to adjust the percent species protection level to account for bioaccumulation were not expressly considered in ANZECC & ARMCANZ (2000). The ANZG (2018) document recommends that constituents with log10 octanol-water partitioning coefficients (log K_{ow}), bioconcentration (log BCF) or bioaccumulation (log BAF) factors greater than or equal to four have potential to cause effects to higher trophic levels. To account for this potential additional form of toxicity, the level of protection provided should be increased (Warne et al., 2018). For toxicants or constituents where bioaccumulation and secondary poisoning effects should be considered, ANZG (2018) states, "to account for the bioaccumulating nature of this toxicant, it is recommended to apply the species protection level default water quality guideline one level above that which would normally be applied (e.g. if 95 percent level of species protection would normally be applied, then the 99 percent default water quality guideline should be used (Warne et al., 2018)."

There are two main types of EQC, EQGs and environmental quality standards (EQSs) as described below:

- EQGs are threshold numerical values or narrative statements, which, if met, indicate there is a high degree of certainty that the associated environmental quality objective has been achieved. Exceedances to EQGs means there is uncertainty as to whether the associated environmental quality objective has been achieved and more detailed assessment against an EQS is triggered. EQGs are generally equivalent to the water quality guidelines described in ANZECC & ARMCANZ (2000; these numerical values are referred to as "trigger values" in ANZECC & ARMCANZ).
- EQSs are threshold numerical values, or narrative statements that indicate a level beyond which there is a significant risk that the associated environmental quality objective has not been achieved, and a management response is triggered.

EQGs based on spatial locations in Cockburn Sound designated as high, moderate and low levels of ecological protection can be found in **Table 1** for metals of interest to the Site. Many of the EQGs adopted for areas of high ecological protection in *Table 2a* of the *EQC Reference Document* are more conservative than the trigger values for slightly to moderately disturbed systems in ANZECC and ARMCANZ (Table 3.4.1).

In addition to the above, the *EQC Reference Document* outlines two other EQC related to the maintenance of the ecosystem integrity:

- LRVs are constituents that may require some form of surveillance and possibly management intervention but where there was insufficient information on toxicity to derive a reliable EQGs; and,
- Initial Management Triggers (IMT), which are designed to assist in assessing the urgency of implementing a management response in areas where water quality has been significantly contaminated.

As LRVs and IMTs are based on limited data and have low reliability, the *EQC Reference Document* suggests that "Neither LRVs or IMTs are recommended benchmarks for assessing environmental performance, but they do provide information that can assist environmental quality management decisions in Cockburn Sound."

TABLE 1 EQGS FOR METALS IN COCKBURN SOUND FROM THE EQC REFERENCE DOCUMENT

Constituent	High Protection (µg/L)	Moderate Protection (µg/L)	Low Protection (µg/L)
Cadmium[b]	0.7	14 [c]	36 [a]
Chromium III	7.7	49	
Chromium VI	0.14	20[c]	
Cobalt	1	14	
Copper *	0.3	3[c]	
Lead	2.2	6.6[c]	
Mercury (inorganic)[b]	0.1	0.7[c]	1.4 [c]
Nickel	7	200 [a]	
Silver	0.8	1.8	
Vanadium	50	160	
Zinc	7[c]	23[c]	

Notes:
µg/L = micrograms per litre
a = "trigger value" may not protect key test species from acute and chronic toxicity (see ANZECC & ARMCANZ 2000).
b = chemical for which possible bioaccumulation and biomagnification effects should be considered (log10 K_{ow} values > 4 and < 7).
c = value may not protect key test species from chronic toxicity (see ANZECC & ARMCANZ 2000).
* = note ANZG is finalising a draft copper marine criteria; this value should be considered in lieu of the above EQG once finalised.

The purpose of this memorandum is to summarise relevant and applicable EQGs for Cockburn Sound adjacent to the Site and to derive EQGs for select metal analytes that are currently based on LRVs or overseas guidelines (aluminium, arsenic, gallium, iron, manganese, molybdenum and selenium). The *EQC Reference Document* does not consider LRVs to be EQGs as there was insufficient toxicity data available at the time of development to derive EQGs with specified levels of protection (as outlined in the SEP). The LRV metals discussed in *Table 2c* of the *EQC Reference Document* include: aluminium, arsenic (III), arsenic (V), manganese, molybdenum, selenium (IV) and selenium (VI). The LRVs in the *EQC*

Reference Document are sourced from ANZECC & ARMCANZ (2000) or select available overseas guidelines (i.e., arsenic and selenium). Additional metal LRVs sourced from ANZECC & ARMCANZ (2000) and ANZG (2018) include: gallium and iron. These LRV metals were derived by a variety of methods including:

- Adopting values from freshwater toxicity data (gallium);
- Adopting from international jurisdictions (iron); or,
- Through the assessment factor or Acute to Chronic Ratio (ACR) method (aluminium, arsenic, gallium, manganese, molybdenum and selenium).

Table 2 summarises the metal LRVs from the EQC Reference Document.

TABLE 2 LRVS FOR METALS IN COCKBURN SOUND FROM THE EQC REFERENCE DOCUMENT

Constituent	High Protection (µg/L)	Moderate Protection (µg/L)	Low Protection (µg/L)	Available Overseas Guidelines [a] (µg/L)
Aluminium	0.5	--	--	
Arsenic III	2.3	--	--	12 [c]
Arsenic V	4.5	--	--	12.5 [d] 36 [e]
Manganese	80	--	--	
Molybdenum	23	--	--	
Selenium IV [b]	3	--	--	71 [f*]
Selenium VI [b]	3	--	--	

Notes:
µg/L = micrograms per litre
a = overseas guidelines provided in this table have been derived to protect marine ecosystems from the chronic effects of contaminants and not for triggering further investigations to determine if chronic effects are occurring.
b = chemical for which possible bioaccumulation and biomagnification effects should be considered (i.e., log10 K_{ow} values >4 and <7).
c = overseas guideline source = South Africa; arsenic III fraction = total
d = overseas guideline source = Canada; arsenic V fraction = total
e = overseas guideline source = United States; arsenic V fraction = dissolved
f = overseas guideline source = United States; selenium IV fraction = dissolved
* = USEPA suggests that the status of the fish community should be monitored if selenium concentration exceeds 5.0 µg/L because the guideline does not take into account uptake via the food chain.

Acceptable Approaches to Derive or Update EQGs

The SEP and *EQC Reference Document for Cockburn Sound* recommended an approach where EQC are derived using one of four possible approaches (listed in order of preference):

1) Locally developed biological effects data;
2) Ecological models;
3) Reference sites; or,
4) Refining default trigger values for local environments.

The framework adopted for applying EQC to Cockburn Sound has been developed to be consistent with the recommended approaches in ANZECC & ARMCANZ (2000). The criteria derived for water quality in Cockburn Sound was developed in 2017 and used the framework from the existing regulations at the time, ANZECC & ARMCANZ (2000). The Australian & New Zealand guidelines for Fresh and Marine Water Quality (ANZG, 2018) and supporting documentation (Warne et al., 2018) provided an update to the ANZECC & ARMCANZ guidelines (2000), which is the guidance followed by this memorandum. The revised guidelines include: some modernised trigger values based on new toxicity data, updated classification of reliability guidelines and updated derivation frameworks. Guidelines for some constituents still don't exist (from any published guideline) as there was not enough toxicity data at the time the guidelines were promulgated. If guidelines don't exist or are "low" or "unknown" reliability, both ANZECC & ARMCANZ guidelines (2000; updated in 2018 to Warne et al., 2018 and ANZG, 2018) and the SEP (Government of Western Australia, 2015) outline frameworks for deriving EQGs for site-specific criteria or to contemporise EQGs promulgated with low confidence.

The recommendation in the case of a LRV exceedance is, "to search for, or test for, more data of sufficient quality or to further assess the likely risk of exposure to the chemical (ANZECC & ARMCANZ, 2000)". The updated guidelines (ANZG, 2018) have similar recommendations for using low, very low or unknown reliability values. LRVs should only be used, in the following circumstances:

- In the interim;
- With a plan to improve the value;
- With other lines of evidence to account for the low reliability and improve the overall confidence in the assessment; and,
- With documented justification for why the LRV is used.

In most cases, EQGs classified as either moderate, low, very low or unknown will have certain data limitations that could be addressed by incorporating additional chronic toxicity data. The preferred method of deriving trigger values is by a metanalysis method which includes available toxicity data of acceptable quality. Using multiple datapoints coalesced in a species sensitivity distribution (SSD) analysis, allows the guideline to be weighted on the dataset rather than the data point of just one organism. In addition, an SSD analysis provides the ability derive multiple levels of protection for the ecosystem through distribution probability.

Critical Review of Low Reliability Values

The objectives of the critical review of LRVs are to:

- Describe the processes and associated technical limitations of each LRV derivation approach; and,
- Summarise the supporting assumptions contributing to each existing metal LRV.

This review is supported by **Attachment A**, which provides a detailed review of the technical information supporting the derivation of each LRV on a metal-by-metal basis. Understanding the information that contributed to the LRVs is a critical step to informing more technically robust EQGs suitable for Cockburn Sound.

Processes and Technical Limitations of LRV Derivation Approaches

Published guidelines have different terms to discuss low reliability criteria. For continuity, we'll use the term "Low Reliability Values" or "LRVs", consistent with the *EQC Reference Document*. LRVs found in the *EQC Reference Document* originated from ANZECC & ARMCANZ (2000). LRVs were derived using four different methods that varied depending on the availability and quality of toxicity data for a given metal analyte. Marine LRVs were established by:

- Using freshwater values where no marine literature exists;
- Through the adoption of guidelines developed by other international regulatory bodies;
- Adoption of background data as the LRV; or,
- By the assessment factor approach.

Each approach used to develop LRVs is discussed in more detail below.

Absence of Marine Literature

The gallium marine LRV was established based on freshwater guideline values. The marine gallium LRV is based on freshwater values because no reliable marine toxicity data were available at the time of guideline development. The disadvantage to using toxicity data from a different media (fresh, marine or estuarine) is that toxicity often varies between fresh and salt water. The effect of salinity, conductivity or other marine-related TMFs (Toxicity-Modifying Factors) are not considered when freshwater EQGs or LRVs are adopted as marine LRVs. Freshwater species are often more sensitive to metals and thus when these values are adopted as marine LRVs they are often very conservative. Details of the derivation process for gallium are provided in **Attachment A.** A summary of the information contributing to the LRV is provided in **Table 3**.

Adoption of International Guidelines

The iron LRV is based on freshwater Canadian guidelines. Adopting toxicity limits that have been set by other countries is a common approach when no suitable limit exists within the ANZG framework. The drawback to this method is that these values may not consider the effects of the local environment or endemic species. In this case, that discrepancy is further emphasized by the fundamental difference in media type between the underlying toxicity dataset and the environment to which it will be applied (freshwater vs. marine). Additional differences also include the types of acceptable toxicity endpoints, the treatment of multiple data for the same species/endpoint, the minimum numbers of trophic levels and endpoints required to generate an SSD, the consideration of toxicity modifying factors and the protection levels for various types of waters. Details of the derivation process for iron are provided in **Attachment A**. A summary of the information contributing to the LRV is provided in **Table 3.**

Other LRV Metals from Overseas Guidance

The *EQC Reference Document* also provides LRVs that employ derivation approaches from overseas guidance. Regulating agencies in other countries have their own guidance to derive water quality criteria. These values can be useful to compare regulations and criteria across international jurisdictions, and per the *EQC Reference Document* should be used in conjunction with LRVs to assist regulators and managers to make informed decisions on acceptable levels of water quality in Cockburn Sound. However, special care should be used in making comparisons or adopting values as methods of derivation differ for various regulators. Criteria included in **Table 2** have been derived to protect marine ecosystems from the chronic effects of contaminants. South Africa's criterion for Arsenic (III) is 12 µg/L, however the methods for derivation of this criteria are inconsistent with the ANZG (2018) SSD derivation approach (Department of Water Affairs and Forestry (DWAF), 1995). The published Arsenic (V) criterion of 36 µg/L is derived from acute Arsenic (III) data converted to a chronic value by an ACR (USEPA, 1984). The selenium criterion of 71 µg/L (USEPA, 1987) is also acute data converted to a chronic value by ACR. Refinement of overseas guidance is warranted to ensure that percent species protection levels can be developed consistent with the moderate level of protection in Cockburn Sound adjacent to the Site.

Adoption of Background Data

Background levels of a constituent in the marine environment can also be used to derive LRVs. In cases where background levels of a constituent are naturally prevalent (for example, boron in seawater), the natural background levels of the constituent are adopted as the LRV. This approach is likely to be conservative; while adverse effects are not expected at ambient background concentrations, this does not imply that measured concentrations above ambient background would result in adverse effects. In this situation, additional toxicity data linking exposure concentrations with effect levels would be required to interpret whether risks may arise. Application of background datasets is discussed in greater detail in the **Assessment of Background Conditions in Cockburn Sound** within this memorandum.

Assessment Factor

Aluminium, arsenic, gallium, manganese, selenium and molybdenum LRVs were all determined by the lowest acute toxicity value using the assessment factor method. Details of the derivation process for these metals are provided in **Attachment A**. A summary of the information contributing to the LRV is provided in Table 3.

The assessment factor approach is the most commonly employed manner to derive LRVs. This approach is comprised of collating available acute ecotoxicity data available for the constituent of interest and dividing it by an assessment factor to derive the LRV as illustrated in **Equation 1**.

EQUATION 1 $$LRV = \frac{LC50}{Assessment\ Factor}$$

Where LC50 is the median (50th percentile) lethal effect concentration (mg/L) for the most sensitive taxa available and assessment factor is an arbitrary assessment factor number (unitless) identified based on the number of toxicological data points available.

The purpose of the assessment factor method is to take available acute, lethal effects data and conservatively adjust the value by an assessment factor to allow for its use in decision-making regarding chronic and chronic non-lethal effects. Due to this, assessment factors applied are often extremely conservative (large numbers). As defined by ANZECC & ARMCANZ (2000) and ANZG (2018), larger assessment factors are applied as datasets get smaller, reflecting the decreasing scale of confidence in the available toxicity data. However, the guidance states that assessment factor values can vary based on scientific judgement and these values often end up assigned arbitrarily.

Assessment factors are often unsupported by any empirical or theoretical information. Many authors have acknowledged that assessment factors are arbitrary, have no theoretical scientific basis (Hart, 1974; Nicholson, 1984; Kooijman, 1987; Okkerman et al., 1991; Schudoma, 1994; Rand et al., 1995). The limitations of the assessment factor methods can be summarised as:

- Assessment factor values have no theoretical basis and are often arbitrarily assigned conversion values;
- Generic assessment factors do not relate to empirically derived acute-to-chronic ratios (ACRs) or other meaningful conversions between effect endpoints or exposure durations;
- Water quality guidelines derived using assessment factor approaches may not protect all aquatic life forms; and,
- Application of an assessment factor doesn't provide levels of protection for management decisions (Warne, 1998).

For these reasons, WA EPA (2017), ANZG (2018) and ANZECC & ARMCANZ (2000) suggest that values derived by the assessment factor method cannot qualify as EQGs and are designated as LRVs.

Summary of Low Reliability Values for Metals

Table 3 summarises the derivation approach, available toxicological studies and assessment factors used for each LRV. Details of the derivation process for iron are provided in **Attachment A**.

TABLE 3 SUMMARY OF LOW RELIABILITY VALUES AND ASSOCIATED DERIVATION ASSUMPTIONS

Constituent	LRV (µg/L)	Year Derived	Media	No. Taxa	No. Species	No. Data Points	Group	AF	Species	Duration	Test Type	Toxicity Test	Relevant Endpoint	Effect Conc. (µg/L)	References
Aluminium	0.5	2000	MW	3	6	11	Annelid	200	*Ctenodrilus serratus*	96h	Acute	LC50	Mortality	240	Petrich and Reish, 1979
Arsenic (III)	2.3	2000	MW	2	12		Crustacean	100	*Cancer magister*		Acute		Mortality	232	Martin, et al., 1981
Arsenic (V)	4.5	2000	MW	2	5	10	Crustacean	200	*Mysidopsis bahia*	96h	Acute	LC50	Mortality	893	Lussier, 1984
Gallium	18	2000	FW	1	2	3	Fish	200	*Cypirinus carpio*	3d	Chronic	LC50	Mortality	2,400	Hildebrand and Cushman, 1977
Iron	300	2018	FW	2	3		Fish								CCREM, 1987
Manganese	80	2018	MW	3	6		Mollusc	200	*Crassostrea virginica*	48h	Acute	LC50	Mortality	16,000	Calabrese et al., 1973
Molybdenum	23	2018	MW	1	2	2	Diatom	200	diatom			EC50	Growth	4,500	Wilson, 1980
Selenium	3	2018	MW	3	13	34	Mollusc	100	*Argopecten irradians*	96h	Acute	LC50	Mortality	255	Nelson et al., 1988

Notes:
µg/L = micrograms per litre
AF = assessment factor
d = day
EC50 = 50 percent effect concentration
FW = freshwater
h = hour
LC50 = 50 percent effect concentration
MW = marine water
No. = number
NOEC = no observed effect concentration

EQGs Identified or Derived for Select Metal LRVs

The approach to identify and derive EQGs for select LRV metals is described below. The most recent toxicological literature supporting the LRVs as noted in ANZECC & ARMCANZ (2000) was carried out in the mid-1990s; therefore, approximately 30 years of scientific research are not captured by existing LRVs. ANZG (2018) guidance warns against including toxicity data published prior to 1980 as the data are considered more likely to be unreliable due to advances in experimental and analytical capabilities since that time (Warne, 1998). Many LRVs are calculated solely based on toxicological literature that was conducted prior to 1980. Although particularly aged studies can be seminal pieces of research to support decision making, antiquated study design and analytical technology can limit the utility of these studies in modern SSD-based criteria derivation. The HRVs have been calculated with more contemporary data (including data collected over the last 20 years) and higher quality studies and are therefore considered suitable for future screening assessments of groundwater and surface water quality data.

This assessment was focused on aluminium, arsenic, gallium, iron, manganese, molybdenum and selenium based on the understanding of Site COPECs. For constituents where adequate contemporised ecotoxicity data exists, we describe the process for deriving contemporary EQGs in accordance with Warne et al. (2018). Since the development of LRVs in ANZECC & ARMCANZ (2000) and ensuing update in ANZG (2018), significant research has been undertaken to understand the toxicity of select inorganic compounds known to be associated with alumina refineries in the marine environment (Golding et al., 2022; van Dam et al., 2018). These studies were carefully reviewed and form important basis for EQGs for select metals.

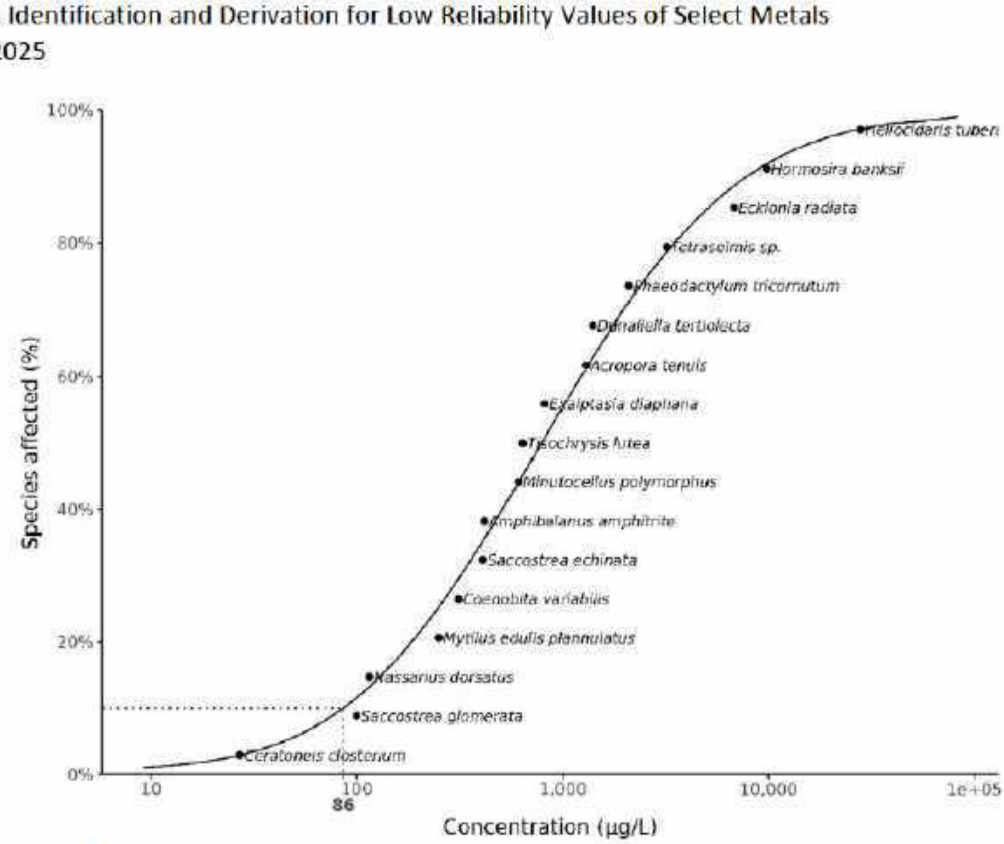
A summary of the literature search for contemporised toxicity data and refined EQGs identified is provided for each relevant LRV metal below. A comprehensive literature review was conducted to obtain studies used in the derivation of the previous metal LRVs as well as a forward-looking literature search to identify studies derived since the 1980s. Online peer-reviewed literature database repositories were searched for key terms like "chronic marine [metal] toxicity" and forward and backward literature searches were conducted from citation lists of identified papers.

Aluminium

Since the derivation of this guideline value in 2000, numerous studies have published new toxicity data on aluminium in marine waters. Golding et al. (2014), developed a high reliability marine water quality guideline based on a metanalysis of 11 datasets. The metanalysis combined two values from previous publications and new data generated from nine temperate and tropical species. The toxicity data presented are chronic 10 percent inhibition or effect concentrations (IC10 or EC10) and no-observed-effect concentrations (NOECs) from 11 species across 6 taxonomic groups (Golding et al., 2014). Tropical organisms may have been underrepresented in Golding et al. (2014) and several studies on the toxicity of aluminium to tropical organisms were subsequently published by Trenfield et al. (2015, 2016 and 2017) and van Dam et al. (2016a, 2016b). The above toxicity data was assembled in a metanalysis by van Dam et al. (2018).

Since the 2024 Derivation Memo (EHS Support, 2024) was submitted, aluminium marine DGVs were finalised by ANZG (ANZG, 2025). The finalised marine DGVs explicitly build upon the dataset of van Dam et al. (2018) and allow for the assessment of high (9 µg/L), moderate (72 µg/L) and low (160 µg/L) ecological protection areas within Cockburn Sound. However, these finalised DGVs for aluminium contain technical deficiencies that need to be considered prior to their adoption more broadly. First, ANZG (2025) employed Burrlioz 2.0 software to derive the criteria. Second, the 27 µg/L diatom mixed temperate and tropical species geometric mean toxicity value is being reported twice per Table 1 of ANZG (2025) and could be misconstrued as being double counted in the derivation process, which would incorrectly produce much lower values when that table is extracted and derived using ssdtools. Finally, the calculation of the *Paracentrotus lividus* embryo abnormality final toxicity value reported in Appendix B of ANZG (2025) has appreciable embryo abnormality in the control and should not be considered in the SSD approach. Therefore, the ANZG (2025) input dataset has been modified to remove the *P. lividus* toxicity value (32 µg/L), and the amended dataset was then analysed using ssdtools v2.2.0 consistent with the SET recommendations to derive updated EQGs. The amended ANZG (2025) data was used to produce the SSD shown in **Figure 3**.

The SSD considered a total of ten studies covering 17 species to derive a very high reliability EQG. Protection levels derived included the 99th percent = 9.2 µg/L, 90th percent = 86 µg/L and 80th percent = 190 µg/L. As the area adjacent to the Site is in a zone of moderate ecological protection, the 90th percent species protection level of 86 µg/L should be used as the EQG to screen monitoring data. While these updated EQGs derived using ssdtools v2.2.0 show close alignment to those derived in ANZG (2025) using Burrlioz 2.0, the model-averaged distribution fit by ssdtools provides a more robust classification of the underlying toxicity data than the single model fit applied by Burrlioz. Therefore, while the adjustment seems marginal, the ssdtools method is technically superior and the resulting guideline values are more defensible. In light of the noted technical deficiencies in ANZG (2025), the EQGs derived using ssdtools will be preferred for monitoring areas of high, moderate and low ecological protection in Cockburn Sound, respectively. The ANZG (2025) criteria will also be considered for screening purposes while additional review of the technical deficiencies is conducted by the Audit Team. Further discussions with the Audit Team are warranted to review relevant and applicable datasets needed to derive more refined site-specific Tier 3 criteria.



Notes:

Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level
The *P. lividus* toxicity value (32 µg/L) from the ANZG (2025) dataset was removed for this derivation due to appreciable embryo abnormality in the control.

FIGURE 3 SPECIES SENSITIVITY DISTRIBUTION OF MARINE ALUMINIUM TOXICITY DATA FROM ANZG (2025)

Arsenic

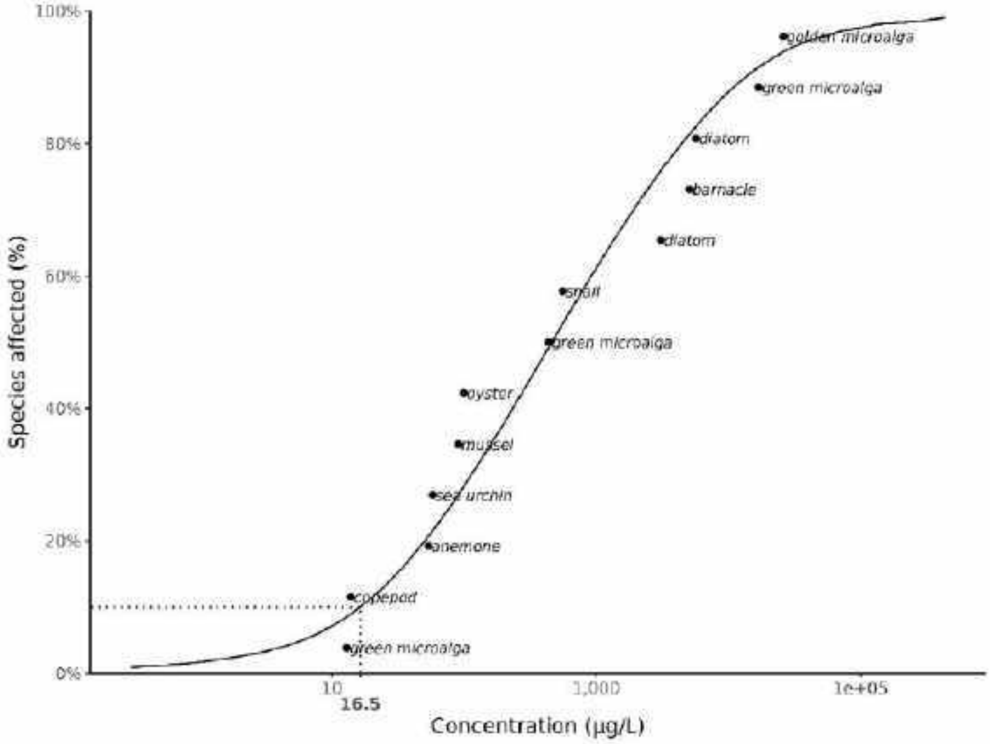
Since publication of the LRV for arsenic, Golding et al. (2022) generated chronic toxicity data for arsenic (V) from 13 temperate and tropical marine species representing seven taxonomic groups. This study was undertaken specifically to fill the data gap of chronic arsenic toxicity data and to derive a new EQG to replace the arsenic (V) LRV. With this goal, the paper clearly outlines the step-by-step process by which they follow the derivation process outlined by Warne et al. (2018). The methods outline the process by which they calculate chronic EC10 toxicity data and utilise the SSD methodology by employing Burrlioz software (CSIRO, n.d.) for the analysis to derive an EQG for arsenic (V) for taxa specific to Australia.

Since the publication of the Golding et al. (2022) study, the NWQMS has agreed to transition from the use of Burrlioz software to ssdtools. Therefore, the Golding et al. (2022) dataset has been re-analysed with ssdtools v2.2.0 and the updated EQG is reported below.

This EQG has been adopted as the basis for comparison of arsenic (V) and total arsenic concentrations as arsenic is most often present as arsenic (V) in the marine environment. The EQG based on the data of Golding et al. (2022) for arsenic (V) is a higher quality EQG than the current LRV because it:

- Has upgraded from a LRV to a moderate reliability EQG;
- Includes toxicity data for a greater number of species rather than using the assessment factor method which uses a single acute toxicity datapoint and assessment factor;
- Includes toxicity data for a greater number of taxonomic groups; and,
- Incorporates both tropical and temperate data.

The SSD considered multiple studies to derive a moderate reliability EQG for arsenic (V) and total arsenic. Protection levels derived included the 99th percent = 0.30 µg/L, 90th percent = 17 µg/L and 80th percent = 51 µg/L. These are the EQGs identified for areas of high, moderate and low ecological protection in Cockburn Sound, respectively. As the area adjacent to the Site is in a zone of moderate ecological protection, the 90th percent species protection level of 17 µg/L should be used as the EQG to screen monitoring data at the Site. The data published by Golding et al. (2022) was used to reproduce the SSD shown in **Figure 4**.



Notes:

Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level
90th percent species protection level has subsequently been rounded to two digits per Warne et al. (2018)

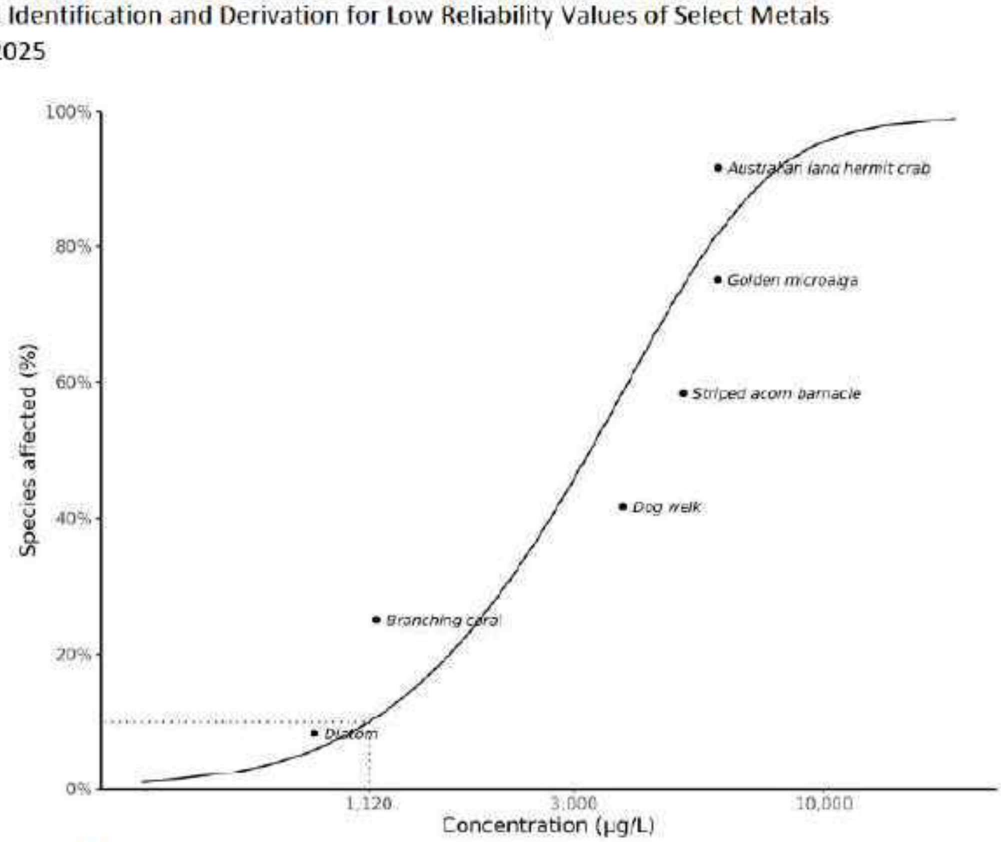
FIGURE 4 SPECIES SENSITIVITY DISTRIBUTION OF MARINE ARSENIC TOXICITY DATA FROM GOLDING ET AL. (2022)

Gallium

A metanalysis by van Dam et al. (2018) joins toxicity data published since 2000 in an SSD analysis using Burlioz software to derive a new EQG for gallium. The analysis was used to derive a new EQG following the method described by Warne et al. (2015). While revisions in methodology have been developed by Warne et al. (2018), these changes do not materially impact on the criteria derivation. However, since the publication of the van Dam et al. (2018) study, the NWQMS has agreed to transition from the use of Burrlioz software to ssdtools. Therefore, the van Dam et al. (2018) dataset has been re-analysed with ssdtools v2.2.0 and the updated EQGs are reported below. Species protection levels derived included the 99th percent = 370 µg/L, 90th percent = 1,100 µg/L and 80th percent = 1,700 µg/L thresholds. These are the EQGs identified for areas of high, moderate and low ecological protection in Cockburn Sound, respectively.

There is limited toxicity data for gallium such that many regulating entities, Australian nor international authorities, do not have a guideline in place (such as the Canadian Council of Ministers of the Environment (CCME) or USEPA). The toxicity of six taxa considered in the SSD range from a diatom EC10 at 860 µg/L (*Ceratoneis Closterium*) to a few taxa that are more tolerant: a hermit crab (*Coenobita variabilis*) EC10 at 6,010 µg/L and microalgae (*Tisochrysis lutea*) NOEC of 6,000 µg/L. These measured marine toxicity values and calculated EQG are significantly greater (~40x greater) than the conservative freshwater EQG previously developed for gallium. This proposed marine EQG is only considered low reliability because of the fit of the data to the SSD distribution. Nevertheless, the derived EQG is significantly more technically robust when compared to the LRV that used assessment factor approaches on freshwater ecotoxicity data.

It is noted draft marine DGVs for gallium are currently under consideration by ANZG. If they are finalised, they will be adopted as the EQGs for Cockburn Sound. The EQGs derived from the van Dam et al. (2018) data will be used in the interim. As the area adjacent to the Site is in a zone of moderate ecological protection, the 90th percent species protection level of 1,100 µg/L should be used as the EQG to screen monitoring data at the Site. The data published by van Dam et al. (2018) was used to reproduce the SSD shown in **Figure 5**.



Notes:

Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level
90th percent species protection level has subsequently been rounded to two digits per Warne et al. (2018)

FIGURE 5 SPECIES SENSITIVITY DISTRIBUTION OF MARINE GALLIUM TOXICITY DATA FROM VAN DAM ET AL. (2018)

Iron

The marine LRV for iron is 300 µg/L, this value was adopted from the Canadian guideline for freshwater iron (Canadian Council of Resource and Environment Ministers (CCREM), 1987). A review of the literature has identified very few updates to research on marine iron ecotoxicity. However, an EQG for freshwater iron was promulgated in 2024, from an SSD analysis on the chronic toxicity data of 27 species (Environment and Climate Change Canada (ECCC), 2024). This met the CCME minimum guidelines for SSD development and meets the minimum data requirements for at least five species that belong to at least four different taxonomic groups.

Several of the studies included in the analysis assessed how two toxicity-modifying factors (TMFs) to iron, dissolved organic carbon (DOC) and pH, influence toxicity. TMFs were evaluated in Brix et al. (2023) using a multiple linear regression (MLR) model for three species: *Raphidocelis subcapitata, Ceriodaphnia dubia and Pimephales promelas*. The results of the MLR show that DOC was a significant TMF for all three species, while pH was a significant TMF in *R. subcapitata* and *P. promelas* models, but not in the *C. dubia* model. Species-specific equations (**Equation 2, Equation 3** and **Equation 4**) were then developed using the MLR-derived slopes for *R. subcapitata, C. dubia* and *P. Promelas* to account for the influence of pH and DOC on iron toxicity where applicable. These equations were applied to normalise effects concentrations for broader taxonomic groups (freshwater invertebrates, algae, and fish and amphibians, respectively) to develop input datasets that could subsequently be evaluated using an SSD (Brix et al., 2023).

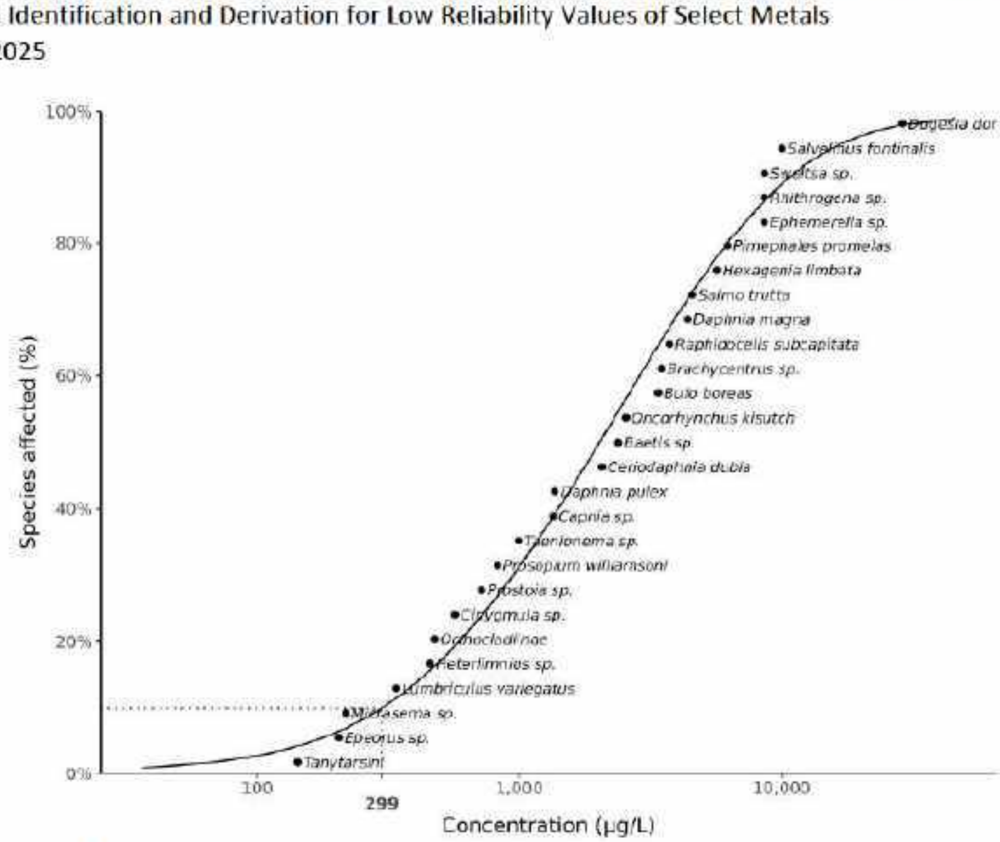
EQUATION 2 (INVERTEBRATES)
$$Normalised\ EC = EXP(ln(EC_{meas}) - 0.6 * (ln(DOC_{meas}) - ln(DOC_{target})))$$

EQUATION 3 (ALGAE)
$$Normalised\ EC = EXP(ln(EC_{meas}) - 0.744 * (ln(DOC_{meas}) - ln(DOC_{target})) - 0.322 * (pH_{meas} - pH_{target}))$$

EQUATION 4 (FISH AND AMPHIBIANS)
$$Normalised\ EC = EXP(ln(EC_{meas}) - 1.102 * (ln(DOC_{meas}) - ln(DOC_{target})) - 0.787 * (pH_{meas} - pH_{target}))$$

Notes:
DOC_{meas} = measured DOC concentration of the study
DOC_{target} = target DOC concentration
EC = effects concentration
EC_{meas} = measured effects concentration of the study
ln = natural log
pH_{meas} = measured pH of the study
pH_{target} = target pH

Collated iron toxicity data published by ECCC (2024) were normalised to the median-case background water scenario in Cockburn Sound, where DOC = 1.1 mg/L and pH = 8.2 s.u., utilizing the equations of Brix et al. (2023) above. Normalised data were analysed using ssdtools v2.2.0 and the model-averaged distribution is presented in **Figure 6**. Species protection levels derived included the 99th percent = 36 µg/L, 90th percent = 300 µg/L and 80th percent = 590 µg/L thresholds. As the area adjacent to the Site is in a zone of moderate ecological protection, the 90th percent species protection level of 300 µg/L should be used as the EQG to screen monitoring data at the Site.



Notes:

Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level
90th percent species protection level has subsequently been rounded to two digits per Warne et al. (2018)

FIGURE 6 SPECIES SENSITIVITY DISTRIBUTION OF IRON TOXICITY DATA FROM ECCC (2024)

Six additional model scenarios were evaluated with a static pH of 8 s.u. and varying DOC concentrations (1.0, 1.1, 1.2, 1.3, 1.4 and 1.5 mg/L) to highlight the influence of increasing DOC on species percent level estimates. The results for each scenario examined are reported in **Table 4**. Values for high protection areas (99th percentile) range from 36 µg/L to 44 µg/L and increase with greater DOC concentrations. Values for moderate protection areas (90th percentile) and low protection areas (80th percentile) show the same pattern. Moderate protection values range from 280 µg/L to 360 µg/L and low protection values range from 540 µg/L to 710 µg/L.

This assessment highlights that 1) water quality directly influences iron toxicity; and, 2) since the effect concentrations in the input dataset are based on toxicity in freshwater systems, the EQG values reported here may not be applicable to the marine environment. Therefore, the EQG values for iron based on the median-case background scenario (DOC = 1.1 mg/L and pH = 8.2 s.u.) will be adopted as the interim EQGs for the purpose of advancing the program noting that further evaluation could be required to develop a reliable set of EQGs that are protective of receptors in Cockburn Sound.

TABLE 4 POSSIBLE IRON EQGS BASED ON VARIABLE PH AND DOC

Species Protection Level (%)	Ecological Protection Level	DOC (mg/L)						
		1	1.1	1.1*	1.2	1.3	1.4	1.5
99%	High	39	40	**36**	41	42	43	44
90%	Moderate	280	300	**300**	310	330	350	360
80%	Low	540	570	**590**	610	640	680	710

Notes:

All updated values have been rounded to two significant digits per Section 3.6 of Warne et al., (2018).

EQG results (µg/L) were computed with a pH = 8 s.u. unless otherwise indicated.

EQG results were derived using freshwater toxicity data and should be considered interim EQGs noting that further evaluation of their applicability to the marine environment could be required.

Interim EQG values denoted in bold text.

*pH = 8.2 s.u.

DOC = dissolved organic carbon

mg/L = milligrams per litre

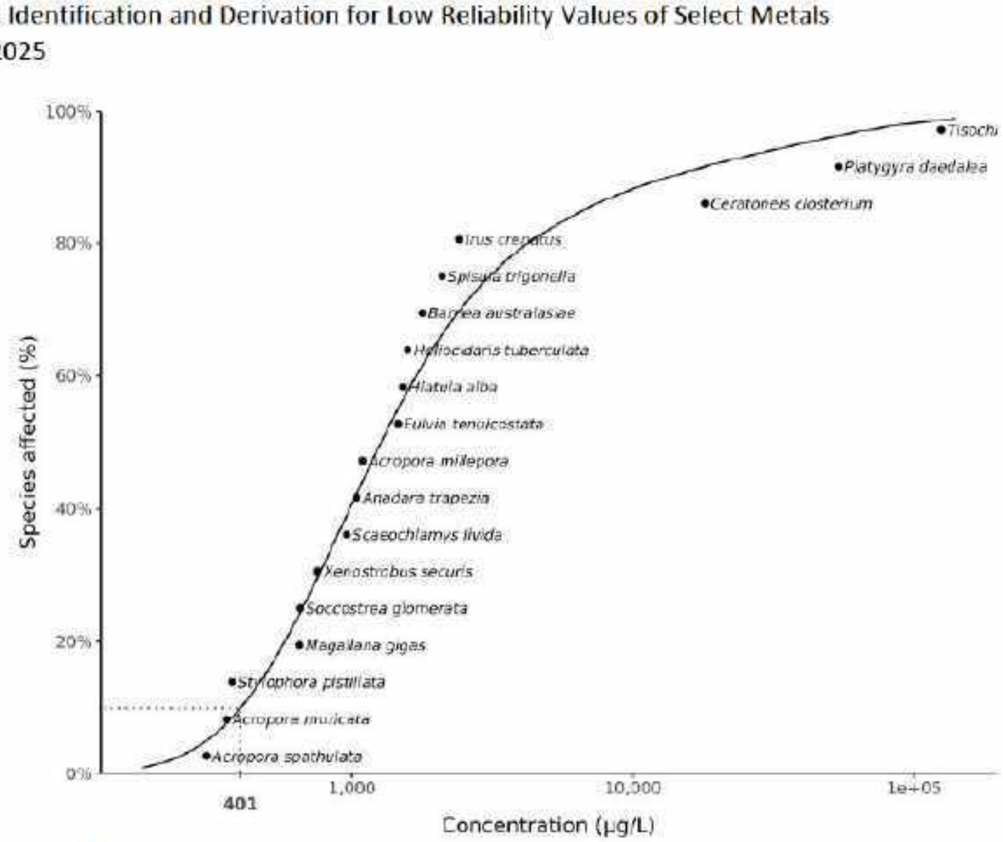
s.u. = standard units

µg/L = micrograms per litre

Manganese

Since the publication of the current LRV for manganese, Golding et al. (2023) has collated 184 acute and chronic marine toxicity datapoints from literature sources of acceptable quality. This dataset was subsequently refined to 18 toxicity values representing individual species from five taxonomic groups per the guidance of Warne et al. (2018). The stated objective of the Golding et al. (2023) study was to provide robust marine water quality guideline values for marine systems in order to improve the current LRV. The combined dataset was analysed using both Burrlioz 2.0 and ssdtools v0.1.1 software to produce two sets of moderate reliability guideline values. However, since the publication of the Golding et al. (2023) study, the ssdtools software has undergone substantial updates and is currently published as v2.2.0 (Thorley et al., 2025). Therefore, the Golding et al. (2023) dataset has been re-analysed using the latest version of ssdtools v2.2.0. Protection levels derived included the 99th percent = 180 µg/L, 90th percent = 400 µg/L and 80th percent = 580 µg/L thresholds. These are the EQGs identified for areas of high, moderate and low ecological protection in Cockburn Sound, respectively.

As the area adjacent to the Site is in a zone of moderate ecological protection, the 90th percent species protection level of 400 µg/L should be used as the EQG to screen monitoring data at the Site. The data published by Golding et al. (2023) was used to reproduce the SSD shown in **Figure 7**. It is noted draft marine DGVs for manganese are currently under consideration by ANZG. If they are finalised, they will be adopted as the EQGs for Cockburn Sound. The EQGs derived from the Golding et al. (2023) data will be used in the interim.



Notes:

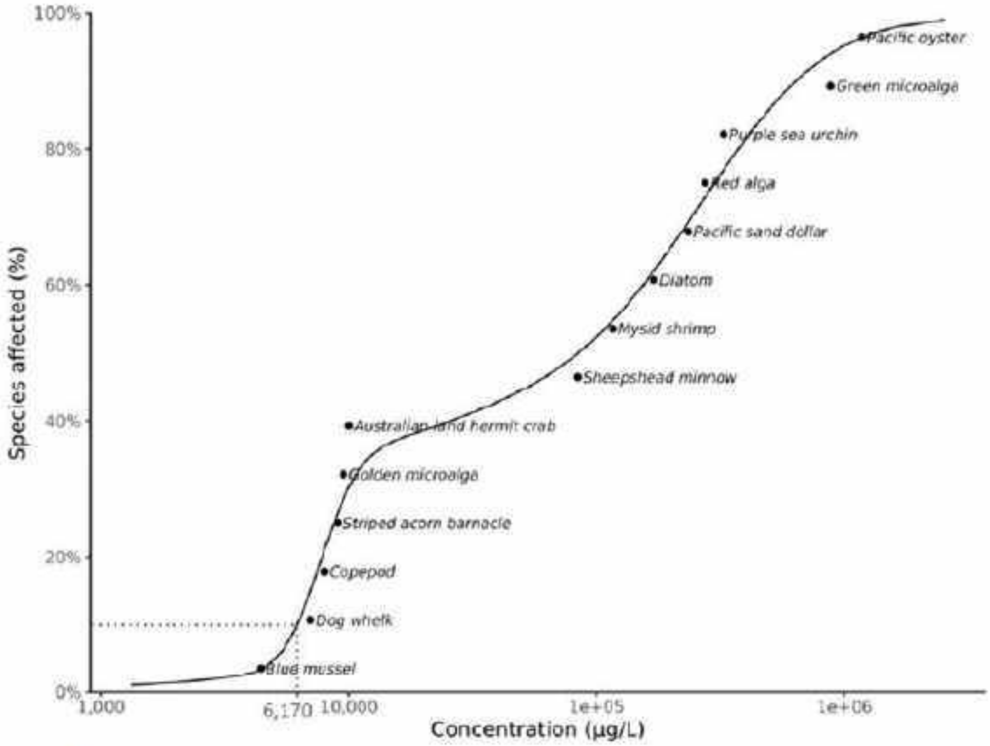
Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level
90th percent species protection level has subsequently been rounded to two digits per Warne et al. (2018)

FIGURE 7 SPECIES SENSITIVITY DISTRIBUTION OF MANGANESE TOXICITY DATA FROM GOLDING ET AL. (2023)

Molybdenum

A metanalysis by van Dam et al. (2018) combines data published since 2000 in an SSD analysis to derive a new EQG for molybdenum. The analysis followed the method of Warne et al. (2015), a predecessor to Warne et al. (2018) with the same guiding principles. Ten of the 14 available data points are from a study specifically looking to close data gaps for the toxicity of molybdenum (Heijerick et al., 2012). The available data range from 4.4 mg/L EC10 for the Blue Mussel (*Mytilus edulis*; Morgan et al., 1986) to an 1,174 mg/L EC10 for the Pacific Oyster (*Crassostrea gigas*; Heijerick et al., 2012). The addition of extra available data points allowed derivation of a moderate reliability EQG (due to the amount of data available and the fit of the data). The data published by van Dam et al. (2018) was used to reproduce the SSD shown in **Figure 8.**

It is noted that the distribution of the underlying data in **Figure 8** appears bimodal. The model-averaged fit for this data produced by ssdtools v2.2.0 is dominated by the log-normal mixture distribution, which performs best on bimodal datasets. While this fitted SSD highlights the flexibility of the ssdtools software to reliably fit a broad range of input dataset structures, it also suggests an existent gap in the van Dam et al. (2018) dataset and highlights a need for additional marine molybdenum toxicity studies to improve data coverage.



Notes:

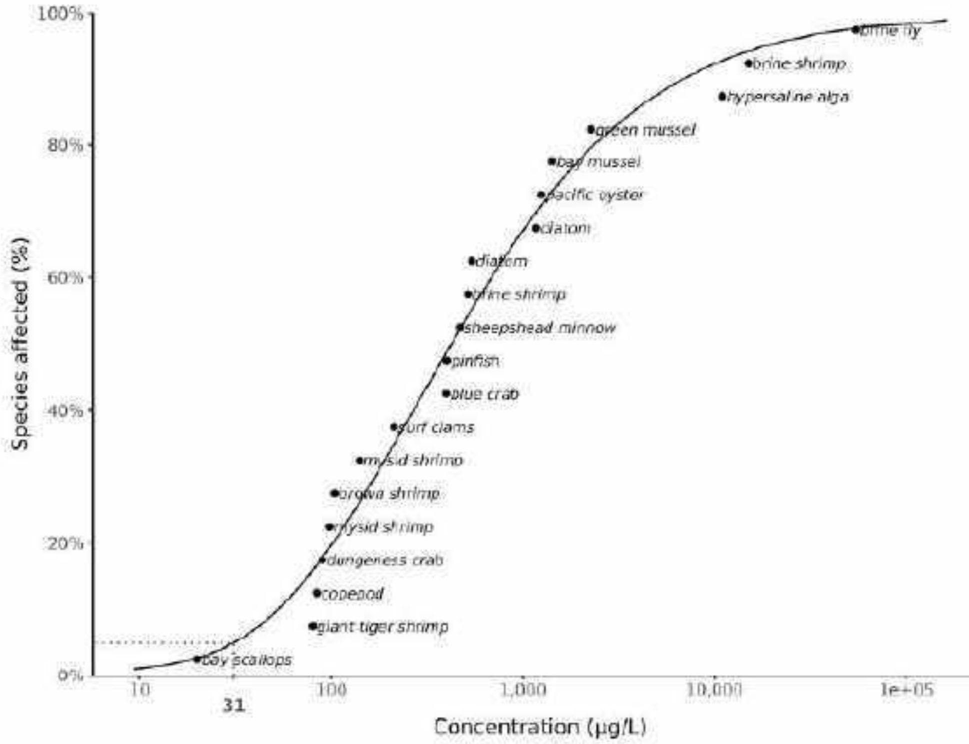
Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level
90th percent species protection level has subsequently been rounded to two digits per Warne et al. (2018)

FIGURE 8 SPECIES SENSITIVITY DISTRIBUTION OF MOLYBDENUM TOXICITY DATA FROM VAN DAM ET AL. (2018)

A total of six studies covering 14 species were analysed to derive the 99th percent = 1,300 µg/L, 90th percent = 6,200 µg/L and 80th percent = 7,800 µg/L levels of species protection. These are the EQGs identified for areas of high, moderate and low ecological protection in Cockburn Sound, respectively. As the area adjacent to the Site is in a zone of moderate ecological protection, the 90th percent species protection level of 6,200 µg/L should be used as the EQG to screen monitoring data at the Site. It is noted draft marine DGVs for molybdenum are currently under consideration by ANZG. If they are finalised, they will be adopted as the EQGs for Cockburn Sound. The EQGs derived from the van Dam et al. (2018) data will be used in the interim.

Selenium

No adequate EQGs were identified in the literature for selenium in the marine environment; thus, derivation was necessary. The current LRV for selenium is 3 µg/L and is based on a single effect concentration estimated using nominal concentration data (Nelson et al., 1988). Following the stepwise guidance on EQG derivation utilising the SSD approach in the ANZG (2018) guidance, a total of eight studies (Brix et al., 2004; Forsythe et al., 1994; Glickstein, 1978; Karthikeyan et al., 2019; Martin et al., 1981; Nagarjuna et al., 2018; Nelson et al., 1988 and Ward et al., 1981) were collated, classified and assessed for quality. Data were screened, prioritising chronic data where possible and converting acute data to chronic when necessary. This dataset is considered 'preferred' as it covers 20 species and six taxonomic groups, exceeding the minimum data requirements. The SSD approach (**Figure 9**) utilised ssdtools v2.2.0 software to derive the 99th percent = 9.3 µg/L, 95th percent = 31 µg/L and 85th percent = 76 µg/L protection levels. These are considered moderate reliability EQGs for areas of high, moderate and low ecological protection in Cockburn Sound, respectively. Further details on the derivation process can be found in **Attachment C**.



Notes:

Black line indicates the model-averaged probability distribution line of best fit
Dashed line indicates 90th percent species protection level

FIGURE 9 SPECIES SENSITIVITY DISTRIBUTION FOR MARINE SELENIUM ECOTOXICITY DATA

Selenium is known to bioaccumulate, which triggers the application of the species protection level default water quality guideline one level above that which would normally be applied (e.g., if the 90th percent level of species protection would normally be applied, the 95th percent level of species protection should be used (Warne et al., 2018; ANZG, 2018)). It should be acknowledged that this adjustment is a surrogate approach that does not directly consider potential risks to higher order biota which may be exposed through dietary uptake. To establish greater confidence in the protectiveness of the derived EQGs for selenium, an additional lines-of-evidence assessment was conducted to directly consider the bioaccumulation pathway in Cockburn Sound (**Attachment D; Attachment** E). This assessment included a qualitative evaluation of available site-specific sea star (*Archaster angulatus*) tissue data and quantitative dietary modelling (Presser and Luoma, 2010).

The robust lines-of-evidence assessment revealed two key findings:

1. Selenium tissue concentrations observed in a key invertebrate receptor species (*A. angulatus*) adjacent to the Site do not differ significantly from those observed in background areas over 11 km away, and,
2. Surface water concentrations of selenium associated with adverse effects in waters adjacent to the Site range from 322 µg/L to 726 µg/L.

These findings demonstrate that both the 99th percent species protection level of 9.3 µg/L and the 95th percent species protection level of 31 µg/L generated through the SSD are protective of higher trophic levels and as a site-specific limit, respectively. However, there are acknowledged uncertainties associated with this lines-of-evidence assessment, specifically regarding parameterisation of the quantitative dietary model, that preclude the adoption of the 95th percent species protection level (31 µg/L) derived for Site monitoring efforts at this time.

Additional model refinement through the collection of site-specific parameters is recommended to reduce acknowledged uncertainties and develop a more reliable EQG that is protective of receptors in Cockburn Sound. Focused Site sampling efforts should capture instantaneous measurements of particulate and dissolved selenium fractions in the water column across different spatial and temporal (i.e., tidal) scales in Cockburn Sound. In addition, collection of interstitial porewater samples would also provide increased confidence in the equilibrium relationship between matrices in the active marine environment. The resulting, robust dataset will provide an understanding of the fractional distribution and concentration of selenium present adjacent to the Site and in background areas and will refine our understanding of mixing dynamics and geochemical processes within the intertidal and subtidal zones. Until refinement occurs, the 95th percentile background concentration of 10 µg/L will be adopted as the interim selenium EQG for the purpose of advancing the program.

Assessment of Background Conditions in Cockburn Sound

The EQC Reference Document highlights that EQGs should never be below natural (un-impacted) background concentrations. Therefore, assessment of background surface water concentrations in Cockburn Sound can be used in the instance where EQGs are less than background by providing a secondary line of evidence for comparison as per the *EQC Reference Document*. The objectives of this assessment are to:

- Summarise sources of background surface water data considered;
- Discuss the standardisation methods used to align the data from multiple sources;
- Describe the marine background data evaluation approach; and,
- Report on background marine surface water adjacent to the Site.

In total, 49 samples were included in the assessment, which were obtained during field investigations conducted in 2001, 2006, 2011 and 2023. Data obtained for samples analysed for aluminium, arsenic, chromium, gallium, iron, lead, manganese, mercury, molybdenum, selenium, uranium and vanadium were used to establish 95th percentile background concentrations (of the distribution). The 95th percentile is suitable for comparison of areas of moderate level of ecological protection as stipulated by the *EQC Reference Document*.

Sources of Background Data Considered

Analytical data from nearby marine background areas located to the north and south of the Site were compiled from several sources. The below summary describes the datasets considered, approximate sampling location and analytes included.

Datasets from the following sources were included in calculating the marine background:

- **Oceanica 2012 *Alcoa Nearshore Survey 2011 Data Report*.** This report includes data from offshore sampling events conducted in 2001, 2006 and 2011 adjacent to the Site and in background areas located to the north and south of the Site.
  - Two samples were collected on each of seven transects. Transect seven, located near Robbs Jetty, was considered North Background. Transect four, located to the South of the Site, was considered South Background.
  - Analytes included total and dissolved metals and other major ions.
- **Additional 2023 sampling conducted by Alcoa and Ecotech.** These samples were collected two background areas based on their description. North of Jetty Contractors Yard was considered South Background, Up Gradient Sample Noot Boat Ramp was considered North Background, Location data were not provided for these samples but were estimated based on the description of the locations Samples were collected in March and April 2023.
  - Analytes included dissolved metals, major ions and other general chemical parameters.

Standardisation of Marine Background Datasets

For each dataset, the following steps were conducted to prepare and standardise the data to allow for preliminary assessment:

1. Review the locations sampled and standardise sample naming and location conventions (locations converted to Map Grid of Australia 1994 datum);
2. If required, digitise datasets from PDFs and conduct QA/QC to ensure accurate data conversion;
3. Convert datasets to 'long' format with one row per sample, per analyte to generate comparable datasets;
4. Combine field and lab datasets (if possible) to enable comparison of field parameters and analytical results;
5. Standardise analyte names by assigning a Chemical Abstracts Service Registry Number (CAS-RN) value to each analyte present in the data;
6. Standardise sample date and time formats (if present);
7. Convert results to standardised units for each analyte;
8. Determine the fraction (total or dissolved) for each analysis to the extent possible based on reports and communications with Alcoa; where no information was available results were assumed to be total.

Marine Background Data Evaluation

Data from areas north and south of the Site were evaluated for differences or similarities in concentrations. No substantial variation was noted between the concentration of metals constituents; therefore, marine background data were combined across locations. The 95th percentile concentration was calculated for each parameter to estimate the upper limit of measured background conditions. For this calculation, non-detect values were set to ½ of the laboratory reported quantitation limit to avoid inflating background estimates based on practical quantitation limits. Background data were summarised separately for total and dissolved fractions to allow comparison of the differences in cases when data on both total and dissolved concentrations of analytes were available.

Data from each of these sources was standardised as described in the sections above; however, not all results are comparable given differences in sampling locations, analyses and sampling methods. While efforts were made to avoid duplicating data and to ensure that data were correctly standardised, combining datasets across sources inherently introduces some potential for error. Data standardisation and preparation (other than transformation/assignment of spatial location data) was conducted. A summary of the background dataset is found in **Attachment B**. The calculated 95th percentile background concentrations can be found in **Table 5**.

TABLE 5 BACKGROUND LEVELS OF SITE METALS

		Background (95th percentile)		Number of Background Datapoints (n)	
Constituent	Units	Dissolved	Total	Dissolved	Total
Aluminium	µg/L	77.85	14.2	50	10
Arsenic	µg/L	77.18	1.81	49	10
Chromium (III)	µg/L	12.5		37	
Gallium	µg/L	4.12	1	49	10
Iron	µg/L	29.1		39	
Lead	µg/L	1.5		39	
Manganese	µg/L	2.2		2	
Mercury*	µg/L	0.05	0.05	10	10
Molybdenum	µg/L	40.3	12	48	10
Selenium*	µg/L	10	1	49	10
Uranium	µg/L	3.42	3.455	9	10
Vanadium	µg/L	3.88	2	49	10

Notes:
µg/L = micrograms per litre
* constituents known to bioaccumulate

The 95th percentile background concentrations should be applied to new EQG as referenced in the and *EQC Reference Document for Cockburn Sound*: "Consistent with ANZECC & ARMCANZ (2000), for a high level of ecological protection a new EQG for a water quality indicator would be derived from the 20th percentile and/or 80th percentile of the natural background levels for that indicator, or for a moderate level of ecological protection, the 5th and/or 95th percentiles".

Background Conditions Summary

The 95th percentile is suitable for comparison of areas of moderate level of ecological protection as stipulated by the *EQC Reference Document*. The background values in concert with contemporised EQC should be used in screening monitoring data at the Site. Based on the marine background data set described above, a number of constituents have higher background concentrations than the derived EQC. These background values will need to be considered relative to the contemporised guidelines provided in Table 7 below as part of any screening level assessment.

Application of Contemporised Guidelines

The objectives of this section are to

- Summarise the site-specific and contemporised EQGs compiled and derived through this assessment; and,
- Discuss considerations for the application of the EQGs.

Summary of Site-Specific and Contemporised EQGs

The adoption of contemporised EQGs was conducted in a structured, hierarchical approach that relies on local guidance in Western Australia, alternative identified or derived EQGs of suitable quality including that of international standards presented herein, ANZG (2018) and, ANZECC & ARMCANZ (2000). The technical assessment that identified various alternative, contemporised EQGs to replace LRVs addresses an important data gap in previous assessments. EQGs for each constituent were individually scrutinised for the most scientifically-sound basis for assessment against any monitoring data obtained on Site.

The following hierarchy of EQGs was adopted:

- *EQC Reference Document* EQGs for moderate environmental protection
    - Cadmium, chromium, chromium (VI), cobalt, copper, lead, mercury, nickel, silver, vanadium and other non-metal compounds.
- Alternative EQGs established herein to replace select LRV metals:
    - ANZG (2025) – aluminium
    - EHS Support (2023) – selenium (**Attachment C**)
        - Acknowledged uncertainties associated with the lines-of-evidence assessment (**Attachment E**), specifically regarding parameterisation of the quantitative dietary model, preclude the adoption of the 95th percent species protection level (31 µg/L) derived for Site monitoring efforts at this time.
    - Golding et al. (2022) – arsenic and arsenic (V)
    - ECCC (2024) – iron
    - van Dam et al. (2018) – gallium, molybdenum
    - Golding et al. (2023) – manganese
- ANZG (2018)
    - Zinc (2021)
    - All other metals EQGs in EQC sourced from ANZG (2018)
    - Other non-metal compounds
- ANZECC & ARMCANZ (2000)
    - Antimony and boron retained as described.
- Site-specific marine background data
    - Oceanica (2012) and 2023 data collected by Alcoa.
    - Selenium (**Attachment C**)
        - The 95th percentile background concentration has been adopted as the interim EQG for the purpose of advancing the program noting that further assessment could be required to develop a reliable EQG that is protective of receptors in Cockburn Sound.

Contemporised criteria to replace or upgrade LRVs have been identified or derived to support decision making in Cockburn Sound. Areas in Cockburn Sound have been designated with varying levels of ecological protection based on current and historical land and water use. An illustration of the spatial distribution of areas of low, moderate and high levels of ecological protection defined by the SEP is provided in **Figure 2**. The figure illustrates that the majority of the Site is situated in a zone classified as moderate ecological protection, with a portion of the southern end of the Site (closest to a neighbouring industrial area) in an area of low ecological protection. Further, as noted above the area around the jetty could be considered an area of low ecological protection due to routine navigational dredging activities. The contemporised criteria are provided in **Table 6**. The adopted values consist of a combination of current EQGs and upgraded LRVs based on the criteria hierarchy listed above.

TABLE 6 CONTEMPORISED CRITERIA FOR COCKBURN SOUND

Constituent	Units	High Ecological Protection	Moderate Ecological Protection	Low Ecological Protection	EQG Source	Derivation Source	Data Source
Ammonia as N	µg/L		1,200		ANZECC (2000)	ANZECC (2000)	ANZECC (2000)
Dissolved Oxygen	%		80		ANZECC (2000)	ANZECC (2000)	ANZECC (2000)
Nitrate as N	µg/L		100,000		ANZECC (2000)	ANZECC (2000)	ANZECC (2000)
pH	s.u.		9		*EQC Reference Document*	*EQC Reference Document*	*EQC Reference Document*
Aluminium†	µg/L	9.2	86	190	EHS Support (2025)	EHS Support (2025)	ANZG (2025)
Antimony	µg/L		270		ANZECC (2000)	ANZECC (2000)	ANZECC (2000)
Arsenic (III)	µg/L		2.3		N/A	ANZECC (2000)	ANZECC (2000)
Arsenic (V)	µg/L		4.5		N/A	ANZECC (2000)	ANZECC (2000)
Arsenic	µg/L	0.30	17	51	EHS Support (2025)	EHS Support (2025)	Golding et al. (2022)
Boron	µg/L		5,100		ANZECC (2000)	ANZECC (2000)	ANZECC (2000)
Calcium	µg/L		NC		NC	NC	NC
Cadmium*	µg/L	0.7	14	14	*EQC Reference Document*	ANZG (2018)	ANZG (2018)
Chromium (III)	µg/L	7.7	49		*EQC Reference Document*	ANZG (2018)	ANZG (2018)
Chromium (VI)	µg/L	0.14	20		*EQC Reference Document*	ANZG (2018)	ANZG (2018)
Copper	µg/L	0.3	3		*EQC Reference Document*	ANZG (2018)	ANZG (2018)
Gallium	µg/L	370	1,100	1,700	EHS Support (2025)	EHS Support (2025)	van Dam et al. (2018)
Iron§	µg/L	36	300	590	EHS Support (2025)	EHS Support (2025)	ECCC (2024)
Lead	µg/L	2.2	6.6		*EQC Reference Document*	ANZG (2018)	ANZG (2018)
Manganese	µg/L	180	400	580	EHS Support (2025)	EHS Support (2025)	Golding et al. (2023)
Mercury*	µg/L	0.1	0.7	0.7	*EQC Reference Document*	ANZG (2018)	ANZG (2018)
Molybdenum	µg/L	1,300	6,200	7,800	EHS Support (2025)	EHS Support (2025)	van Dam et al. (2018)
Nickel	µg/L	7	200		ANZG (2018)	ANZG (2018)	ANZG (2018)
Selenium*‡	µg/L		10		Background Dataset	--	Various Sources
Uranium	µg/L		15		CCME (2011)	ANZECC (2000)	ANZECC (2000)
Vanadium	µg/L	50	160		*EQC Reference Document*	ANZG (2018)	ANZG (2018)

Constituent	Units	High Ecological Protection	Moderate Ecological Protection	Low Ecological Protection	EQG Source	Derivation Source	Data Source
Zinc	µg/L	303	23		ANZG (2021)	ANZG (2021)	ANZG (2021)
Carbon Disulfide	µg/L		20		ANZECC (2000)	ANZECC (2000)	ANZECC (2000)

Notes:
EQC Ref Doc = Environmental Quality Criteria Reference Document for Cockburn Sound
% = percent
s.u. = standard units
µg/L = micrograms per litre
*Constituents for which bioaccumulation is a consideration. In accordance with *EQC Reference Document for Cockburn Sound* and ANZG (2018), the high, moderate and low ecological protection levels correspond to the 99, 95 and 85th LOP as ANZG (2018) states, "to account for the bioaccumulating nature of this toxicant, it is recommended to apply the species protection level DEQG one level above that which would normally be applied (e.g. if 95 percent level of species protection would normally be applied, then the 99 percent DEQG should be used (Warne et al., 2018)." In this case, the marine area adjacent to the Site is a moderate (90 percent LOP) and accounting for bioaccumulation we apply the 95th percent species protection level. These are the values shown in **Table 6.**
** Select non-metals are listed in **Table 6.** Non-metals not listed will be sourced as described in the hierarchy of EQGs above.
† Additional discussion with the Audit Team is warranted pertaining to the use of this derived value when compared to that of ANZG (2025).
‡ The 95th percentile background concentration has been adopted as the interim EQG for the purpose of advancing the program noting that further assessment could be required to develop a reliable EQG that is protective of receptors in Cockburn Sound.
§ Iron values were derived using freshwater toxicity data and should be considered interim EQGs noting that further evaluation of their applicability to the marine environment could be required.

This comprehensive list of contemporised criteria should be used in accordance with the SEP and *EQC Reference Document for Cockburn Sound* for assessing environmental quality. Additional details pertaining to potential measurement approaches and other considerations for the application of EQGs in Cockburn Sound are provided below.

Considerations for Application of EQGs

The contemporised EQGs compiled herein are considered to be appropriate for the assessment of aqueous phase environmental monitoring data collected adjacent to the Refinery in Cockburn Sound. As per the *EQC Reference Document for Cockburn Sound*, "the extent of the area from which environmental quality data are to be collected and compared against the EQC will depend on the objective of the monitoring and reporting program and will therefore need to be established on a case-by-case basis and clearly defined in the monitoring program."

It is important to ensure that monitoring programs are designed to provide the appropriate level of temporal and spatial coverage to adequately characterise the area in question and minimise potential uncertainty from variable monitoring data. On the basis that the criteria are based on chronic exposures, receptors must experience prolonged exposure before deleterious effects will be observed.

For contemporised EQGs compiled herein, the approach adopted for completing a screening level assessment of data and determining whether a potential significant and unacceptable change has occurred, is consistent with ANZECC & ARMCANZ (2000) and comprises the following stepwise approach:

- Compare the 95th percentile of the receiving environment monitoring data with the EQC. If there are no exceedances, then potential effects are considered unlikely; and
- If a constituent from the assessment described in the previous step exceeds the EQC compare the 95% percentile for that constituent to the calculated background. If the concentration does not exceed background, then there is no incremental increase in risk over background.
- If the concentration exceeds the EQC and background a potential significant and unacceptable change may be occurring, and further evaluation of risk (Tier 2 or Tier 3) is recommended.

Conclusions

This assessment provides a review of the regulations from the SEP, *EQC Reference Document* and other applicable Australian guidance (ANZECC and ARMCANZ, 2000; ANZG, 2018) governing water quality compliance in Cockburn Sound, Western Australia. Clearly defining relevant and applicable criteria for the marine environment is fundamental to the assessment of ecological risk and evaluation of risk management requirements.

Contemporised toxicity data and criteria have been identified through this assessment and considered applicable for the comparison to marine surface water and sediment pore water in Cockburn Sound adjacent to the Refinery. Robust criteria for several LRVs were identified by extensive literature searches and subsequent derivation in accordance with methods outlined by ANZG (2018) and Warne et al. (2018).

The established EQGs leverage recent advancements in toxicity data in the last two to three decades since LRVs were developed. The contemporised EQGs represent a significant improvement for LRVs over existing criteria used at the Site to assess conditions in Cockburn Sound, as these contemporised EQGs (aluminium, arsenic, gallium, iron, molybdenum, manganese and selenium) have a higher reliability and utilise a more robust technical approach. No changes to the existing HRVs have been made with many of these values incorporating more contemporary data as described in ANZG 2018 and subsequent addendums.

The contemporised EQGs can be coupled with a suitable monitoring program to enable detailed assessment of Cockburn Sound and provide a high degree of certainty that the associated environmental quality objective has been achieved.

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Attachment A Detailed Technical Basis for Low Reliability Values

Attachment A Detailed Technical Basis of Metal Low Reliability Values

Introduction

Low Reliability Values (LRVs) are designated as such because they are derived from insufficient toxicity data to qualify as a guideline in the *Environmental Quality Criteria (EQC) Reference Document for Cockburn Sound* ("*EQC Reference Document*"). The LRVs in the *EQC Reference Document* were developed based on the toxicity data available when the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ) guidance was adopted in 2000. Thus, many LRVs are based on toxicological literature from over 20 years prior to guidance publication. The updated guidance, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018), states that LRVs should only be used in the following circumstances:

- In the interim;
- With a plan to improve the value;
- With other lines of evidence to account for the low reliability and improve the overall confidence in the assessment; and,
- With documented justification for why the LRV is used.

Published guidelines have different terms to discuss low reliability criteria. For continuity, we'll use the term "Low Reliability Values" or "LRVs", consistent with the *EQC Reference Document*.

LRVs found in the *EQC Reference Document* originated from ANZECC & ARMCANZ (2000). LRVs were derived using four different methods that varied depending on the availability and quality of toxicity data for a given metal analyte. LRVs for marine metals were established by:

- Adoption of freshwater values where no marine literature exists;
- Adoption of guidelines developed by other international regulatory bodies;
- Adoption of background data as the LRV; or,
- By the assessment factor approach.

Each approach used to develop LRVs is discussed in the **Critical Review of Low Reliability Values** section of the *Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals Memorandum*.

LRVs have previously been used as screening criteria when no other criteria are available. Previous investigations into groundwater contamination at Alcoa Kwinana Refinery in Navy Base, Australia have used LRVs as assessment criteria as LRVs were the only values available. The Mandatory Auditor's Report (MAR; Senversa, 2018) noted that several existing exceedances of ecological criteria were attributed to metals with LRVs. As discussed in the MAR and Golder (2017), site metals with concentrations exceeding Tier 1 ecological criteria are as follows:

- Aluminium, gallium, iron, manganese and molybdenum exceed LRVs;
- Arsenic and selenium exceed other overseas guidelines; and,
- Chromium (III), vanadium and zinc exceed moderate protection EQGs.

LRVs are not recommended for assessing environmental performance, but they do provide managers with information that can assist with decision-making regarding environmental quality in Cockburn Sound. Understanding how LRVs are derived is critical to understanding the technical limitations of their application. A detailed description of the technical basis of the LRVs with known exceedances at the Site (listed above), in addition to marine LRVs listed by ANZECC & ARMCANZ (2000; antimony and boron) is described below.

Objectives

The objectives of the critical review of LRVs are to:

- Summarise the supporting assumptions contributing to each existing metal LRV; and,
- Provide a detailed review of the technical information supporting the derivation of each LRV on a metal-by-metal basis.

Understanding the information that contributed to the LRVs is a critical step to informing more technically robust EQGs suitable for Cockburn Sound.

Detailed Technical Basis for Low Reliability Values for Metals

Information contributing to marine metal LRVs are detailed below. The purpose of this assessment is to review the derivation process for LRVs for metals of interest at the Site and highlight the available toxicological information that contributed to each metal LRV. Understanding the detail in the derivation process for individual metals highlights the assumptions contributing to the LRV development and associated challenges for application.

Aluminium

The ANZG (2018) LRV for aluminium in the marine environment is 0.5 µg/L. The marine aluminium LRV was originally developed as part of the ANZECC and ARMCANZ guidance (2000). Acute toxicity data was available for six species across three taxonomic groups. However, given the number and quality of toxicological studies, the assessment factor approach was applied to the most sensitive taxa. Among the toxicological studies evaluated in ANZECC, the lowest value is from a 96-hour survival study on the annelid *Ctenodrilus serratus*, with an LC50 of 97 µg/L (Petrich and Reish, 1979). The LC50 identified for the polychaete was a factor of 2.5 times lower than the next most sensitive taxa. The most tolerant taxon was a crustacean, *Nitocra spinipes*, which had an LC50 of 10,000 µg/L. An assessment factor of 200 was adopted "because the environmental concern level (ECL) factor of 1,000 was considered excessive for such a commonly found element" (ANZECC & ARMCANZ, 2000).

Golding et al (2015) report states that "pristine oceanic dissolved aluminium concentrations are near 0.019 mg L in the Southern Ocean (Middag et al., 2011), whereas relatively uncontaminated coastal waters such as those in Port Hacking (New South Wales, Australia) have concentrations in the 1.2 mg to 1.8 mg Al/L range (J. King, 2013, Honours thesis, University of Wollongong, Wollongong, Australia)." Limited technical basis was provided for the selection of the alternative assessment factor for aluminium. The lack of consideration to the natural background concentration of aluminium also demonstrates that the application of the assessment factor approach results in an arbitrary limit that does not consider empirical observations of chronic aluminium effects or marine water background.

Aluminium concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Golder, 2022; Senversa, 2018). Extensive research has been undertaken since the above LRV was adopted to understand the toxicity of aluminium in marine systems and is identified as an opportunity for further refinement.

Antimony

The existing ANZG (2018) LRV for antimony in the marine environment is 270 µg/L. The marine antimony LRV was originally developed as part of the ANZECC and ARMCANZ guidance (2000). The marine toxicity data for antimony was limited to three species across two taxonomic groups (fish and crustaceans). The lowest toxicity value (two crustacean species, *Carcinus maenas* and *Palaemon serratus*, 24h–9 d LC50 267,000–534,000 µg/L; Amiard, 1976) was divided by an assessment factor of 1000 (due to the limited data). This chronic value was a factor of two times lower than the other two taxa (which also happened to be the most sensitive taxa as data for only three species were available). Antimony was not considered to be a metal of interest at the Site (Golder, 2014; Senversa, 2018) and is not found in appreciable quantities in Bauxite ore (Golder, 2017).

Arsenic

Arsenic exists in four oxidation states: V, III, 0 and –III (Maher and Butler, 1988; Sharma and Sohn, 2009). Approximately 90 percent or more of total arsenic in aerobic seawater is present as inorganic arsenate (arsenic (V)) with the most abundant oxyanion being $HAsO_4^{2-}$(Sadiq, 1990; Neff, 1997). However, arsenic (III) is more toxic than arsenic (V) to marine organisms. A summary of the LRVs for arsenic (III) and arsenic (V) is provided below.

The existing ANZG (2018) LRV for arsenic (III) in the marine environment is 2.3 µg/L. The marine arsenic (III) LRV is low reliability interim trigger value originally developed as part of the ANZECC and ARMCANZ guidance (2000). There were no screened marine toxicity data for arsenic (III), so the low reliability (interim) value of 2.3 µg/L was derived from the unscreened data available from the USEPA (1986). Data came from 12 marine organisms with acute toxicity values ranging between 232 µg/L (zoeae of the Dungeness crab) and 16,030 µg/L (Atlantic silverside) comprised of three fish and eight invertebrate genera. The most sensitive genus, *Cancer*, was 69 times more sensitive than the most resistant, *Menidia*. A standard assessment factor of 100 was used to calculate the EQG given the and low reliability guidelines and the size and diversity of the dataset (USEPA, 1986).

Like arsenic (III), the existing arsenic (V) LRV in the marine environment is a LRV developed in 2000 (ANZECC and ARMCANZ, 2000). The existing LRV for arsenic (V) is 4.5 µg/L. At the time of development, chronic toxicity data for arsenic (V) in the marine environment was only available for two taxonomic groups (crustaceans and algae) and five species. The current low reliability (ECL) marine guideline trigger value of 4.5 µg/L was derived using the lowest LC50 value (a crustacean, *Mysidopsis bahia* 96-h LC50 of 893 µg/L; Lussier, 1984) and an assessment factor of 200. The assessment factor of 200 was used because the limited data were chronic.

Arsenic concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Senversa, 2018). Extensive research has been undertaken since the above LRV was adopted to understand the toxicity of arsenic in marine systems and is identified as an opportunity for further refinement.

Boron

The existing LRV for boron in the marine environment is 5,100 µg/L. This figure was adopted as the LRV for the marine environment as marine toxicity data for boron was only available for two species of fish (4–12 d LC50; 12,200–88,300 µg/L), which is insufficient to derive an EQG. Instead of deriving a LRV on the limited data, the background concentration of boron in seawater 4,500–5,100 µg/L (Kennish, 1989; Stumm & Morgan, 1995) was adopted as the LRV. This LRV was originally developed in 2000 as part of the ANZECC and ARMCANZ guidance (2000). Boron was not considered to be a metal of interest at the Site (Golder, 2014; Senversa, 2018) and is not found in appreciable quantities in Bauxite ore (Golder, 2017).

Gallium

Neither ANZG (2018) nor ANZECC and ARMCANZ guidance (2000) had marine toxicity data to derive a marine EQG for gallium. Therefore, the freshwater LRV for gallium was used in lieu of a marine LRV. The existing LRV for freshwater gallium is 18 µg/L which is based on three datapoints for two species of freshwater fish. The two fish were rainbow trout, *Oncorhynchus mykiss* (28-day LC50; 3,510 µg/L) (Birge et al., 1980) and the common carp, *Cyprinus carpio* (3-day no endpoint recorded, 2,400 to 17,000 µg/L; Hildebrand and Cushman, 1977). From this, a freshwater LRV was derived using an assessment factor of 200 because the study was chronic (ANZECC & ARMCANZ 2000). Because of the deficiency of marine toxicity data, many other regulating entities do not have guidelines for gallium in marine environments.

Gallium concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Golder, 2022; Senversa, 2018). Extensive work has been undertaken since the above LRV was adopted to understand the toxicity of gallium in marine systems and is identified as an opportunity for further refinement.

Iron

The existing ANZG (2018) LRV for iron in the marine environment is 300 µg/L. At the time of the ANZECC derivation, no adequate data on marine iron toxicity was available. Therefore, the marine iron LRV was adopted from the Canadian guideline for marine iron (CCREM, 1987) as part of the ANZECC and ARMCANZ guidance (2000) as a low reliability (interim) trigger value. The data considered for the CCREM-derived guideline came from 3-week LC50 for *Daphnia magna* of 5,900 µg/L (Biesinger and Christensen, 1972), EC50 for fathead minnow of 1,500 µg/L (Sykora et al., 1972) and the safe concentration for exposure of juvenile brook trout ranged between 7,500 µg/L and 12,500 µg/L (CCREM, 1987).

Iron concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Senversa, 2018). Extensive work has been undertaken since the LRV was adopted to understand the toxicity of iron in marine systems and is identified as an opportunity for further refinement.

Manganese

The existing ANZG (2018) LRV for manganese in the marine environment is 80 µg/L. The marine manganese LRV was originally developed as part of the ANZECC and ARMCANZ guidance (2000). The limited data come from six species that belong to three taxonomic groups, and the two lowest available toxicity data points were removed as they were considered anomalous (Lowest Observed Effect Concentration (LOEC) for a crustacean at 10 µg/L and a value for EC50 for algae at 1,500 µg/L). The next lowest toxicity data available was for the American Oyster, *Crassostrea virginica*, with a 48-h LC50 of 16,000 µg/L (Calabrese et al., 1973). The maximum toxicity data available at the time of derivation was a crustacean LOEC of 70,000 µg/L, which is four times greater than the toxicity data used for derivation of the LRV. An assessment factor of 200 was used as the lowest toxicity value was chronic. Manganese concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Senversa, 2018). Significant work has been undertaken since the LRV was adopted, thus, this metal has been identified for further refinement.

Molybdenum

The existing ANZG (2018) LRV for molybdenum in the marine environment is 23 µg/L. The marine molybdenum LRV is low reliability trigger value originally developed as part of the ANZECC and ARMCANZ guidance (2000). Marine data for molybdenum toxicity were only available on one species of diatom and one species of dinoflagellate (EC50 values from 4,500 to 18,000 µg/L; Wilson, 1980) which were insufficient to derive a trigger value (ANZECC, 2000). A low reliability Environmental Concern Level (ECL) of 23 µg/L was derived from the limited data. An assessment factor of 200 was used as "molybdenum is an essential element (ANZG, 2018)".

Molybdenum concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Golder, 2022; Senversa, 2018). Extensive research has been undertaken since the above LRV was adopted to understand the toxicity of molybdenum in marine systems and is identified as an opportunity for further refinement.

Selenium

The existing ANZG (2018) LRV for total selenium in the marine environment is 3 µg/L. The marine selenium LRV is a low reliability (interim) trigger value originally developed as part of the ANZECC and ARMCANZ guidance (2000). The selenium LRV was derived from acute toxicity data from three different taxonomic groups (fish, crustacea and mollusca). The available toxicity data for algae did not pass screening criteria and though algae data was not included in the toxicity data as it did not pass screening guidelines, it was included because the addition of the algae data "does give an indication of the sensitivity of alga and it did not drive the size of the LRV — it only modifies the size of the assessment factor (ANZECC and ARMCANZ, 2000)". The inclusion of the algae toxicity data allowed an assessment factor of 100 to be used. The lowest toxicity data available (96-hr LC50 for the bay scallop, *Argopecten irradians* at 255 µg/L; Nelson et al., 1988) used to derive the LRV was almost three times lower than other toxicity data available. In addition, nominal concentrations of the metal were used in the methods to determine the toxicity of the bay scallop. ANZG (2018) guidelines state that studies based on nominal concentrations of chemicals should not be included in EQG derivation.

Selenium concentrations in groundwater were found to exceed Tier 1 ecological criteria at the Site (Senversa, 2018). Extensive research has been undertaken since the above LRV was adopted to understand the toxicity of selenium in marine systems and is identified as an opportunity for further refinement.

Summary of Low Reliability Value Technical Basis

In summary, LRVs were exceeded at the Site and the derivation process for each LRV was variable depending on the available ecotoxicological data. The LRVs for aluminium, antimony, arsenic, boron, gallium, iron, manganese, molybdenum and selenium all have some inherent technical limitations which constrain their utility for use in assessing conditions in Cockburn Sound.

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Attachment B Background Marine Dataset

TABLE B1

Available Background Marine Surface Water Data

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Dissolved Organic Carbon	Dissolved	1.2	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Aluminum	Dissolved	0.04	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Arsenic	Dissolved	0.0054	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Molybdenum	Dissolved	0.016	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Mar-23	--	--	-	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
pH	Total	8.20	pH units	Detect	S Background Area	T4_10	--	--	--	--	N	A
pH	Total	8.20	pH units	Detect	N Background Area	T7_10	--	--	--	--	N	A
pH	Total	8.20	pH units	Detect	S Background Area	T4_40	--	--	--	--	N	A
pH	Total	8.20	pH units	Detect	N Background Area	T7_40	--	--	--	--	N	A
pH	Total	8.10	pH units	Detect	S Background Area	T4_10	--	--	--	--	N	A
pH	Total	8.00	pH units	Detect	S Background Area	T4_40	--	--	--	--	N	A
pH	Total	7.90	pH units	Detect	N Background Area	T7_10	--	--	--	--	N	A
pH	Total	7.90	pH units	Detect	N Background Area	T7_40	--	--	--	--	N	A
Aluminum	Dissolved	0.01	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Aluminum	Dissolved	0.01	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Aluminum	Dissolved	0.009	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Aluminum	Dissolved	0.007	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Aluminum	Dissolved	0.006	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Aluminum	Dissolved	0.005	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Aluminum	Dissolved	0.005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Aluminum	Dissolved	0.005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Aluminum	Dissolved	0.005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Aluminum	Dissolved	0.005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Aluminum	Dissolved	0.005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Aluminum	Total	0.016	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Aluminum	Total	0.012	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Aluminum	Total	0.011	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Aluminum	Total	0.009	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Aluminum	Total	0.008	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Aluminum	Total	0.008	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Aluminum	Total	0.008	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Aluminum	Total	0.005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Aluminum	Total	0.005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Aluminum	Total	0.005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Arsenic	Dissolved	0.0018	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Arsenic	Dissolved	0.0017	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Arsenic	Dissolved	0.0016	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Arsenic	Dissolved	0.0015	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Arsenic	Dissolved	0.0014	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Arsenic	Dissolved	0.0014	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Arsenic	Dissolved	0.0013	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Arsenic	Dissolved	0.0013	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Arsenic	Dissolved	0.0013	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Arsenic	Dissolved	0.0012	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Arsenic	Total	0.0019	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Arsenic	Total	0.0017	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Arsenic	Total	0.0016	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Arsenic	Total	0.0016	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Arsenic	Total	0.0015	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Arsenic	Total	0.0014	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Arsenic	Total	0.0013	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Arsenic	Total	0.0013	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Arsenic	Total	0.0010	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Arsenic	Total	0.0010	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Gallium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Gallium	Total	0.002	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Gallium	Total	0.002	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Gallium	Total	0.001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Mercury	Dissolved	0.0001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Mercury	Total	0.0001	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Mercury	Total	0.0001	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Molybdenum	Dissolved	0.012	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Molybdenum	Dissolved	0.012	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Molybdenum	Dissolved	0.011	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Molybdenum	Dissolved	0.011	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Molybdenum	Dissolved	0.011	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Molybdenum	Dissolved	0.011	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Molybdenum	Dissolved	0.011	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Molybdenum	Dissolved	0.011	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Molybdenum	Dissolved	0.010	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Molybdenum	Total	0.012	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Molybdenum	Total	0.012	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Molybdenum	Total	0.012	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Molybdenum	Total	0.012	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Molybdenum	Total	0.011	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Molybdenum	Total	0.011	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Molybdenum	Total	0.011	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Molybdenum	Total	0.011	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Molybdenum	Total	0.011	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Molybdenum	Total	0.011	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Selenium	Dissolved	0.0005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Selenium	Total	0.002	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Selenium	Total	0.002	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Selenium	Total	0.0005	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Uranium	Dissolved	0.0035	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Uranium	Dissolved	0.0033	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Uranium	Dissolved	0.0033	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Uranium	Dissolved	0.0031	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Uranium	Dissolved	0.0030	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Uranium	Dissolved	0.0030	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Uranium	Dissolved	0.0030	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Uranium	Dissolved	0.0030	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Uranium	Dissolved	0.0030	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Uranium	Total	0.0035	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Uranium	Total	0.0034	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Uranium	Total	0.0034	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Uranium	Total	0.0034	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Uranium	Total	0.0034	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Uranium	Total	0.0034	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Uranium	Total	0.0030	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Uranium	Total	0.0030	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Uranium	Total	0.0030	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Uranium	Total	0.0030	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Vanadium	Dissolved	0.0020	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Vanadium	Dissolved	0.0020	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Vanadium	Dissolved	0.0020	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Vanadium	Dissolved	0.0020	mg/L	Detect	S Background Area	T4_40	--	--	--	--	FD	A
Vanadium	Dissolved	0.0020	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Vanadium	Dissolved	0.0010	mg/L	Non-Detect	S Background Area	T4_10	--	--	--	--	N	A
Vanadium	Dissolved	0.0010	mg/L	Non-Detect	N Background Area	T7_10	--	--	--	--	N	A
Vanadium	Dissolved	0.0010	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	N	A
Vanadium	Dissolved	0.0010	mg/L	Non-Detect	S Background Area	T4_40	--	--	--	--	FD	A
Vanadium	Dissolved	0.0010	mg/L	Non-Detect	N Background Area	T7_40	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	S Background Area	T4_10	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	N Background Area	T7_10	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Vanadium	Total	0.0020	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Vanadium	Total	0.0018	mg/L	Detect	S Background Area	T4_40	--	--	--	--	N	A
Vanadium	Total	0.0016	mg/L	Detect	N Background Area	T7_40	--	--	--	--	N	A
Alkalinity, Bicarbonate (As CaCO3)	Total	110	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Alkalinity, Total (As CaCO3)	Total	110	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Aluminum	Dissolved	0.05	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Arsenic	Dissolved	0.0050	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Gallium	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Iron	Dissolved	0.050	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Lead	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Molybdenum	Dissolved	0.016	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Selenium	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Vanadium	Dissolved	0.0050	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Mar-23	--	--	PEC1098-01	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Hardness (As CaCO3)	Total	6,400	mg/L	Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
pH	Total	8.20	pH units	Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Aluminum	Dissolved	0.05	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Arsenic	Dissolved	0.0050	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Gallium	Dissolved	0.005	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Iron	Dissolved	0.050	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Lead	Dissolved	0.005	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Molybdenum	Dissolved	0.015	mg/L	Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Selenium	Dissolved	0.005	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Vanadium	Dissolved	0.0050	mg/L	Non-Detect	S Background Area	North of Jetty (ContractorsYard)	11-Mar-23	--	--	PEC1098-06	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Hardness (As CaCO3)	Total	6,300	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Aluminum	Dissolved	0.12	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Arsenic	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Vanadium	Dissolved	0.0020	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Mar-23	--	--	PEC1188-01	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Dissolved Organic Carbon	Dissolved	17.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Hardness (As CaCO3)	Total	6,400	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Arsenic	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Molybdenum	Dissolved	0.014	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Vanadium	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Mar-23	--	--	PEC1309-01	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Hardness (As CaCO3)	Total	6,700	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Aluminum	Dissolved	0.02	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Arsenic	Dissolved	0.0026	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Molybdenum	Dissolved	0.018	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Mar-23	--	--	PEC1723-04	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Hardness (As CaCO3)	Total	6,700	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Aluminum	Dissolved	0.06	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Arsenic	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Molybdenum	Dissolved	0.014	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Mar-23	--	--	PEC1723-07	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Dissolved Organic Carbon	Dissolved	1.4	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Hardness (As CaCO3)	Total	6,800	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Aluminum	Dissolved	0.05	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Arsenic	Dissolved	0.0029	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Molybdenum	Dissolved	0.015	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Selenium	Dissolved	0.002	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Vanadium	Dissolved	0.0026	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Mar-23	--	--	PEC1817-03	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Aluminum	Dissolved	0.03	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Arsenic	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Vanadium	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	25-Mar-23	--	--	PEC1868-03	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Hardness (As CaCO3)	Total	6,400	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Aluminum	Dissolved	0.04	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Arsenic	Dissolved	0.0025	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Vanadium	Dissolved	0.0026	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	26-Mar-23	--	--	PEC1868-06	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Dissolved Organic Carbon	Dissolved	1.2	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Aluminum	Dissolved	0.04	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Arsenic	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Vanadium	Dissolved	0.0025	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	28-Mar-23	--	--	PEC1985-01	--	C
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Dissolved Organic Carbon	Dissolved	1.1	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Hardness (As CaCO3)	Total	6,300	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Selenium	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Vanadium	Dissolved	0.0200	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	29-Mar-23	--	--	PEC2065-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Hardness (As CaCO3)	Total	6,600	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Selenium	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Vanadium	Dissolved	0.0200	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	30-Mar-23	--	--	PEC2146-01	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Dissolved Organic Carbon	Dissolved	1.5	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Hardness (As CaCO3)	Total	6,700	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Arsenic	Dissolved	0.0039	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Gallium	Dissolved	0.003	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Molybdenum	Dissolved	0.039	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Selenium	Dissolved	0.006	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Vanadium	Dissolved	0.0030	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	31-Mar-23	--	--	PEC2288-06	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	160	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Alkalinity, Total (As CaCO3)	Total	160	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Hardness (As CaCO3)	Total	6,800	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Aluminum	Dissolved	0.02	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Arsenic	Dissolved	0.0091	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Gallium	Dissolved	0.016	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Molybdenum	Dissolved	0.065	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Selenium	Dissolved	0.028	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Vanadium	Dissolved	0.0042	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	1-Apr-23	--	--	PED0031-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	160	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Alkalinity, Total (As CaCO3)	Total	160	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Arsenic	Dissolved	0.0079	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Gallium	Dissolved	0.008	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Molybdenum	Dissolved	0.049	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Selenium	Dissolved	0.015	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Vanadium	Dissolved	0.0034	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	2-Apr-23	--	--	PED0032-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	170	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Alkalinity, Total (As CaCO3)	Total	170	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Arsenic	Dissolved	0.0061	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Gallium	Dissolved	0.005	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Molybdenum	Dissolved	0.041	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Selenium	Dissolved	0.010	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Vanadium	Dissolved	0.0030	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	3-Apr-23	--	--	PED0033-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Hardness (As CaCO3)	Total	6,400	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Arsenic	Dissolved	0.0200	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Molybdenum	Dissolved	0.012	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Vanadium	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	4-Apr-23	--	--	PED0170-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Alkalinity, Total (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Hardness (As CaCO3)	Total	6,700	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B

TABLE B1

Available Background Marine Surface Water Data

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Aluminum	Dissolved	0.01	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Arsenic	Dissolved	0.0019	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Gallium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Iron	Dissolved	0.010	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Lead	Dissolved	0.001	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Selenium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Vanadium	Dissolved	0.0018	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	5-Apr-23	--	--	PED0255-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Aluminum	Dissolved	0.01	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Arsenic	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Gallium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Iron	Dissolved	0.010	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Lead	Dissolved	0.001	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Molybdenum	Dissolved	0.014	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Selenium	Dissolved	0.001	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	6-Apr-23	--	--	PED0402-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Hardness (As CaCO3)	Total	6,300	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Arsenic	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Molybdenum	Dissolved	0.014	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	10-Apr-23	--	--	PED0537-12	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Alkalinity, Total (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Hardness (As CaCO3)	Total	6,300	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Arsenic	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Molybdenum	Dissolved	0.015	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Vanadium	Dissolved	0.0026	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	11-Apr-23	--	--	PED0537-15	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Hardness (As CaCO3)	Total	6,200	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Arsenic	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Molybdenum	Dissolved	0.014	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Vanadium	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	7-Apr-23	--	--	PED0537-3	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Dissolved Organic Carbon	Dissolved	1.2	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Hardness (As CaCO3)	Total	6,300	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Arsenic	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	8-Apr-23	--	--	PED0537-6	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Dissolved Organic Carbon	Dissolved	1.1	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Hardness (As CaCO3)	Total	6,300	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Arsenic	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Molybdenum	Dissolved	0.014	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	9-Apr-23	--	--	PED0537-9	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Hardness (As CaCO3)	Total	6,100	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Aluminum	Dissolved	0.09	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Arsenic	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Iron	Dissolved	0.230	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Vanadium	Dissolved	0.0034	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	12-Apr-23	--	--	PED0621-3	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Alkalinity, Total (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Dissolved Organic Carbon	Dissolved	1.2	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Hardness (As CaCO3)	Total	6,600	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Aluminum	Dissolved	0.03	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Arsenic	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Iron	Dissolved	0.066	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	13-Apr-23	--	--	PED0689-3	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Dissolved Organic Carbon	Dissolved	1.1	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Arsenic	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Chromium (III)	Dissolved	0.025	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Vanadium	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	14-Apr-23	--	--	PED0745-3	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B

TABLE B1
Available Background Marine Surface Water Data
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Dissolved Organic Carbon	Dissolved	1.1	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Hardness (As CaCO3)	Total	6,400	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Aluminum	Dissolved	0.23	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Arsenic	Dissolved	0.0020	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Molybdenum	Dissolved	0.012	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Vanadium	Dissolved	0.0030	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	17-Apr-23	--	--	PED0863-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Dissolved Organic Carbon	Dissolved	1.0	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Hardness (As CaCO3)	Total	6,100	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Molybdenum	Dissolved	0.012	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	15-Apr-23	--	--	PED0863-06	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Alkalinity, Total (As CaCO3)	Total	120	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Dissolved Organic Carbon	Dissolved	1.1	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Hardness (As CaCO3)	Total	5,900	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Molybdenum	Dissolved	0.011	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Vanadium	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	16-Apr-23	--	--	PED0863-07	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Dissolved Organic Carbon	Dissolved	1.5	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Hardness (As CaCO3)	Total	6,500	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B

TABLE B1

Available Background Marine Surface Water Data

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Aluminum	Dissolved	0.04	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Vanadium	Dissolved	0.0024	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	18-Apr-23	--	--	PED0952-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Dissolved Organic Carbon	Dissolved	1.3	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Hardness (As CaCO3)	Total	6,800	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Molybdenum	Dissolved	0.012	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Vanadium	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	19-Apr-23	--	--	PED1061-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Dissolved Organic Carbon	Dissolved	1.2	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Hardness (As CaCO3)	Total	6,900	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Vanadium	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	20-Apr-23	--	--	PED1099-01	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Dissolved Organic Carbon	Dissolved	1.5	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Hardness (As CaCO3)	Total	6,700	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Aluminum	Dissolved	0.05	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Arsenic	Dissolved	0.0023	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B

TABLE B1

Available Background Marine Surface Water Data

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Molybdenum	Dissolved	0.012	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Vanadium	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	21-Apr-23	--	--	PED1278-01	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Alkalinity, Total (As CaCO3)	Total	140	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Dissolved Organic Carbon	Dissolved	1.3	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Hardness (As CaCO3)	Total	6,700	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Vanadium	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	22-Apr-23	--	--	PED1368-03	--	B
Alkalinity, Bicarbonate (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Alkalinity, Carbonate (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Alkalinity, Hydroxide (As CaCO3)	Total	5	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Alkalinity, Total (As CaCO3)	Total	130	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Dissolved Organic Carbon	Dissolved	1.4	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Hardness (As CaCO3)	Total	6,600	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
pH	Total	8.20	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Chromium (III)	Dissolved	0.005	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Vanadium	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	23-Apr-23	--	--	PED1368-06	--	B
Dissolved Organic Carbon	Dissolved	1.3	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Arsenic	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Manganese	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Vanadium	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	24-Apr-23	--	--	PED1368-08	--	B
Dissolved Organic Carbon	Dissolved	1.1	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
pH	Total	8.10	pH units	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Aluminum	Dissolved	0.02	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Arsenic	Dissolved	0.0021	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B

TABLE B1

Available Background Marine Surface Water Data

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Chemical Name	Fraction	Result	Unit	Detect	Area	Sample Location	Sample Date	Sample Time	Field ID	SDG	Sample Type	Data Source
Gallium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Iron	Dissolved	0.020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Lead	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Manganese	Dissolved	0.0022	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Molybdenum	Dissolved	0.013	mg/L	Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Selenium	Dissolved	0.002	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B
Vanadium	Dissolved	0.0020	mg/L	Non-Detect	N Background Area	Up Gradient Sample (Noot Boat Ramp)	27-Apr-23	--	--	PED1560-02	--	B

Notes:

-- = not Available

mg/L = milligram per litre

S Background Area = South Background Area

N Background Area = North Background Area

Sample Type Notes

N = Normal Sample

FD = Field Duplicate Sample

Date Source Notes

A = Oceanica 2012

B = 2023 Ocean and Recovery Bores

C = 2023 Alcoa Dataset

Attachment C Selenium Environmental Quality Guideline Derivation

Attachment C Selenium Environmental Quality Guideline Derivation

To derive robust site-specific environmental quality guidelines (EQGs) for selenium in Cockburn Sound, a metanalysis was undertaken using available marine ecotoxicity data for selenium. Following the stepwise guidance on EQG derivation utilising the species sensitivity distribution (SSD) approach by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018), a total of eight studies were collated, classified and assessed for quality. Data were screened, prioritising chronic data where possible and converting acute data to chronic when necessary. The size of the compiled dataset is considered 'preferred' according to the criteria outlined in Warne et al. (2018), as it covers 20 species and six taxonomic groups, exceeding the minimum data requirements. Ssdtools v2.2.0 software(Thorley et al., 2025) was used to generate SSDs and derive a 95th percent level of protection (suitable for the evaluation of moderate environmental protection) for selenium of 31 µg /L adjacent to the Alcoa Kwinana Refinery in Western Australia. Other derived levels of protection include the 99th percent and 85th percent species protection levels of 9.3 µg/L and 76 µg/L, respectively. These EQGs are suitable for the evaluation of high and low ecological protection elsewhere within Cockburn Sound. Derived EQGs are considered 'Moderate' reliability based on the 'Preferred' sample size and the good quality fit of the SSD generated using chronic and converted acute toxicity data (Warne et al. 2018). Since selenium is known to bioaccumulate in the aquatic environment, the high, moderate and low ecological protection EQGs were based on the 99th, 95th and 85th percentiles in the cumulative probability distribution, respectively.

To establish greater confidence in the protectiveness of the EQGs for selenium, an additional lines-of-evidence assessment was conducted to directly consider the bioaccumulation pathway in Cockburn Sound (**Attachment D; Attachment E**). There are acknowledged uncertainties associated with this lines-of-evidence assessment, specifically regarding parameterisation of the quantitative dietary model, that preclude the adoption of the selenium EQGs derived for Site monitoring efforts at this time. Additional model refinement through the collection of site-specific parameters is recommended to reduce these uncertainties and develop a reliable EQG that is protective of receptors in Cockburn Sound. Until refinement occurs, the 95th percentile background concentration of 10 µg/L will be adopted as the interim selenium EQG for the purpose of advancing the program. Details of the selenium EQG derivation process are discussed herein.

Introduction

The existing Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) low reliability guideline (LRV) for total selenium in the marine environment is 3 µg/L. The marine selenium LRV is a low reliability (interim) trigger value originally developed in 2000 as part of the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC and ARMCANZ) guidance. The selenium LRV was derived from acute toxicity data from three different taxonomic groups (fish, crustacea and mollusca) allowed an assessment factor (AF) of 100 to be used. The lowest toxicity data available (96-hr LC50 for the bay scallop, *Argopecten irradians* at 255 µg/L; Nelson et al., 1988) was divided by an AF of 100 to yield the LRV. It should be noted that the LC50 for the bay scallop was calculated using nominal concentrations of the metal. ANZG (2018) recommends that studies based on nominal concentrations be carefully evaluated for inclusion in SSD-based derivations. In brief, the LRV for selenium has many inherent weaknesses as it is derived from only one data point and that datapoint was calculated from nominal data. The purpose of this attachment is to step through the ANZG (2018) derivation process for marine selenium and to develop an EQG for moderate environmental protection areas in Cockburn Sound.

The ANZG (2018), states that LRVs should only be used, in the following circumstances: 1) in the interim, 2) with a plan to improve the value, 3) with other lines of evidence to account for the low reliability and improve the overall confidence in the assessment and 4) with documented justification for why the LRV is used. ANZG (2018) and local guidance for the Cockburn Sound in Western Australia, the *EQC Reference Document for Cockburn Sound* detail approaches to develop EQGs or upgrade LRVs to EQGs. The *EQC Reference Document* is based on the guidance available at the time in ANZECC & ARMCANZ (2000). *EQC Reference Document*, ANZG (2018) and Warne et al., (2018) outline a framework to establish EQGs utilising a more technically robust SSD method. The SSD method to derive risk-based limits for aquatic receptors consists of collation of toxicological literature, an assessment of its quality, identification of a single toxicity value per species and distribution fitting using ssdtools v2.2.0 software (Thorley et al., 2025) to calculate guideline values at different levels of protection. SSD approaches are favourable because they consider all available toxicity data rather than just using the most sensitive toxicity data point, allowing for statistical confidence intervals to be calculated and enabling estimation of specific levels of protection from the fitted, model-averaged cumulative probability distribution function. Despite advances in the approach to formally derive EQGs and numerous additional ecotoxicological studies assessing marine metals, few LRVs have been updated since ANZECC & ARMCANZ (2000).

Extensive research has been undertaken on the ecotoxicity of marine selenium in the 20-30 years since the current guideline was developed. The purpose of this document is to leverage the contemporised marine selenium toxicity data and follow the most updated guidelines (ANZG, 2018; Warne et al., 2018) to derive an EQG to upgrade the existing LRV for marine selenium.

Objectives

The objectives of this assessment are as follows:

- Collate and screen the ecotoxicity data available for marine selenium and determine whether 1) it qualifies for inclusion in SSD analysis and 2) enough qualifying data exists to derive an EQG for selenium.
- Select quality data for inclusion in an SSD analysis to derive EQGs for marine total selenium and determine the reliability of the EQGs.
- Reality check the EQG values in reference to EQGs in other jurisdictions.

Document Structure

This document is structured as follows:

- **Overview of Ecotoxicity Data –** provides a review of data considered for EQG derivation and the screening and quality assessment process
- **Species Sensitivity Distribution Analysis** – summarises the results of the SSD analysis and calculated EQGs at different levels of protection
- **Comparison to Other Existing Selenium Limits –** provides an assessment of calculated selenium EQGs in relation to selenium limits in other jurisdictions

Environmental Quality Guideline Derivation Guidance Approaches Considered

The derivation of site-specific EQGs presented herein was informed by the latest ANZG (2018) guidance with the goal of establishing scientifically robust marine EQG values for selenium. The following guidelines were considered:

- Warne, Ms., Batley, G. E., van Dam, R. A., Chapman, J. C., Fox, D. R., Hickey, C. W., & Stauber, J. L. (2018). *Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants – update of 2015 version.*

- Batley, G., van Dam, R., Warne, Ms., Chapman, J., Fox, D., Hickey, C., & Stauber, J. (2018). Technical rationale for changes to the method for deriving Australian and New Zealand water quality guideline values for toxicants. *Australian and New Zealand Governments and Australian State and Territory Governments,* (October), 1–48.

- Environmental Protection Authority (2017). Environmental Quality Criteria Reference Document for Cockburn Sound, Perth, Western Australia.

Overview of Ecotoxicity data

This section describes the data collection and processing steps undertaken to compile a toxicity dataset suitable for use in the SSD analysis.

Collation of Aquatic Ecotoxicity Literature

A comprehensive literature review was conducted to obtain studies used in the derivation of the previous selenium LRV as well as a forward-looking literature search to identify studies derived since 1987, which was the year of study included in the LRV derivation. In total, eight studies were identified using key word searches for iterations of "chronic marine selenium toxicity" using an online peer-reviewed literature database and forward and backward literature searches from citation lists of identified papers. A brief summary of the identified papers is provided below:

- **Brix et al. (2004)** – Examined chronic and acute selenium toxicity in brine shrimp (*Artemia franiciscana*), brine fly (*Ephydra cinerea*) and a hypersaline alga (*Dunaliella viridis*).
- **Karthikeyan et al. (2019)** – Examined chronic and acute selenium and cobalt toxicity to diatoms (*Odontella mobiliensis, Coscinodiscus centralis* and *Skeletonema costatum*), a copepod (*Longipedia weberi*) and mysid shrimp.

- **Nagarjuna et al. (2018)** - Evaluated enzyme activities, histopathological changes due to the effect of acute and chronic definitive toxicity of selenium on giant tiger shrimp (*Penaeus monodon*) and green mussel (*Perna viridis*).
- **Ward et al. (1981)** – Performed acute toxicity tests on five estuarine organisms (*Mysidopsis bahia, Cyprinodon variagatus, Penaeus aztacus, Callinectes sapidus* and *Lagodon rhomboides*) and chronic or early life stage tests were conducted with mysid shrimp (*Mysidopsis bahia*) and sheepshead minnows (*Cyprinodon variagatus*).
- **Forsythe and Klaine (1994)** – Examined selenate toxicity to brine shrimp (*Artemia spp.*) in relation to high and low sulphate levels.
- **Glickstein (1978)** – Evaluated the toxicity of selenium and mercury and the potential modification of mercury toxicity by selenium in embryos of the Pacific oyster (*Crassostrea gigas*) and the larvae of the crab (*Cancer magister*).
- **Nelson et al. (1988)** – Examined the acute toxicity of selenium (and copper, lead and zinc) to juvenile *Argopecten irradians* and *Spisula solidissima*
- **Martin et al. (1981)** – Assessed the toxicity of arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc salts to the embryos of Pacific oyster (*Crassostrea gigas*) and bay mussel (*Mytilus edulis*) and Dungeness crab (*Cancer magister*) larvae.

Screening and Quality Assessment of Aquatic Ecotoxicity Literature

The quality of toxicity studies was determined in accordance with the Warne et al., (2018) guidance to establish whether effects concentration data were qualified for inclusion in the derivation process. **Table C1** and **Table C2** summarise the toxicity data for selenium included in the SSD analysis and the scoring for all toxicity data included.

Scoring guides differ based on the test media (fresh or marine waters), organism type (plant or non-plant) and constituent (metal or non-metal). The data quality 'score' is determined by awarding points based on the methods used to generate the toxicity values. **Table C1** and **Table C2** indicate the 'quality scores' for plant and non-plant studies, respectively and weigh the scores based on the total number of points for each scoring rubric. ANZG (2018) states that "toxicity data with a quality score ≥80% are classed as 'high' quality, data with a quality score of ≥ 50% to < 80% are classed as 'acceptable' quality, whilst data with a quality score of <50% are classed as 'unacceptable' quality. Only 'high' and 'acceptable' quality data can be used to derive EQGs." The scoring results and quality scores for marine selenium (ANZG, 2018) plants and non- plants can be found in **Table C1** and **Table C2.** All ecotoxicity data considered are at least considered "acceptable" for inclusion in guideline derivation.

The guidance (Warne et al., 2018) states that "as a general rule, toxicity data published prior to 1980 should not be included as these data are considered more likely to be unreliable due to advances in experimental and analytical capabilities since that time (Warne, 1998)". We chose to include one paper published prior to 1980 (Glickstein, 1978), as the methods described returned data quality scores of 89 which are considered "high quality" as described above.

Data were classified as acute or chronic according to the taxa-specific acute and chronic toxicity framework outlined by Warne et al., (2018). The acute vs chronic decision-making scheme considers the taxa, life stage, relevant endpoints and test duration to ultimately determine if tests occur for a short or substantial portion of the organism's life. These acute or chronic designations for the data included can be found in **Table C3.**

Selection of Data to Calculate Single Toxic Effects Concentration per Species

Since a single data point is used to represent the sensitivity of each species in an SSD, some studies overlapped in the species tested for selenium toxicity. The process of curating the available toxicity data followed two guiding principles by Warne et al. (2018):

1) "The preferred order of statistical estimates of chronic (and acute) toxicity to calculate site-specific WQGs is: NEC/EC/IC/LCx (where x ≤10), BEC10, EC/IC/LC15-20 and NOEC. In many cases, only chronic NOEC data will be available, and these may be used" and,
2) "Chronic data are always preferred in the derivation of WQGs over acute data. In situations where acute toxicity data is available, acute data can be converted to chronic data by applying an acute to chronic ratio (ACR). In absence of an ACR for a particular toxicant, a default ACR of 10 can be applied".

To summarise, chronic data was prioritised over acute data (as emphasised frequently by Warne et al., 2018). Where chronic data were unavailable, acute data converted to chronic by applying an acute-to-chronic ratio (ACR; Warne et al., 2018; Batley et al., 2018). Per the guidance of Warne et al. (2018), ACRs were calculated when a study presented chronic and acute data for a single species. ACRs are calculated by the division of the acute toxicity value (LC/EC50) by the chronic toxicity value (NOEC/EC10). Published ACRs were available for two species, *Mysidopsis bahia* of 7.085 (USEPA, 1987; Ward et al., 1981) and sheepshead minnow 10.96 (USEPA, 1987; Ward et al., 1981). ACRs were calculated for *Penaeus monodon* (ACR = 42; data from Nagarjuna et al., 2018), *Perna viridis* (ACR = 12.5; data from Nagarjuna et al., 2018), *Artemia franciscana* (ACR = 5.2; data from Brix et al., 2004) and *Dunaliella viridis* (ACR = 4.1; data from Brix et al., 2004). ACRs were applied to convert acute data to chronic using guidelines outlined by Warne et al. (2018), such that taxa-specific ACRs were used where available and a generic ACR (ACR = 9.0) was used when a taxa-specific ACR was not available. A generic ACR was calculated by the geometric mean of the taxa specific ACRs (Warne et al., 2018). In cases where there were insufficient chronic EC/IC/LCx (where x ≤ 10) data to derive a GV using the SSD method, chronic LC50 values for *Mytilus edulis* and *Crassotrea gigas* were divided by 5 to provide estimates of chronic NOEC/EC10 data per the guidance of Warne et al. (2018).

A single toxicity value per species was selected by following the guidance outlined by Warne et al. (2018). If a single toxicity value was available, it was adopted for that species. If more than one toxicity value was available for a given species, endpoint and duration, the geometric mean was calculated for those values. Following any species/endpoint geometric mean calculations, the lowest toxicity value across all endpoints was adopted. The final toxicity data included in the SSD is shown in **Figure C1.**

Minimum Data Requirements

Minimum data requirements for EQG derivation using the SSD approach include five species belonging to four taxonomic groups as defined by the following groups: fish, amphibians, crustaceans, insects, molluscs, annelids, echinoderms, rotifers, hydra, green algae, diatoms, brown algae, red algae, macrophytes, blue-green algae (cyanobacteria), bacteria, protozoans, coral and fungi (Warne et al., 2018). The collated marine selenium dataset includes 20 species across six taxonomic groups which meets the above stated minimum data requirements.

Multimodal Distributions

The selenium ecotoxicity data were also screened for multimodal distributions. The guidance poses four questions to assist with screening for multimodal distributions:

1) *Is there a specific mode of action that could result in taxa-specific sensitivity?*
Selenium is an essential micronutrient for humans and other animals, but the essentiality of selenium to plants is still debated (Gupta and Gupta, 2017). Selenium exerts its biological functions via molecules called selenoproteins, containing the amino acid selenocysteine (Nessel and Gupta, 2023). This amino acid is used in pathways that organic hyperoxides and hydrogen peroxide, serves a role in making DNA form RNA and assist with thyroid hormones and hormone metabolites (Nessel and Gupta, 2023). In plants, selenium in low doses protects from variety of abiotic stresses such as cold, drought, desiccation and metal stress (Gupta and Gupta, 2017). We have not encountered any specific mode of action that could directly explain taxa specific sensitivity. Visual inspection of the SSD shows that different taxa or phyla are well dispersed across the model-averaged, cumulative probability distribution. Therefore, no focused consideration of taxa or group specific toxicity is considered warranted at this time.

2) *Does the dataset suggest bimodality?*
We did not detect multimodal distributions in the dataset as indicated by visual inspection of the SSD (**Figure C1**) and a calculated bimodality coefficient (BC). The equation for the BC is shown in **Equation B1**, where γ = skewness, κ = excess kurtosis and n = sample size.

EQUATION B1 BIMODALITY COEFFICIENT

$$BC = \frac{\gamma^2 + 1}{\kappa + \frac{3(n-1)^2}{(n-2)(n-3)}}$$

The calculated BC for the selenium dataset was 0.41. Because this value is less than the threshold indicating bimodality (BC=0.555) it is unlikely the dataset is multimodal.

3) *Do the data show taxa-specific sensitivity (that is through distinct grouping of different taxon types)?*
   Visual inspection of the SSD (**Figure C1**) shows that different taxa or phyla are well dispersed across LC50 values. Certain taxa are not more or less sensitive to selenium than other taxa.

4) *Is it likely that indications of bimodality or multimodality or distinct clustering of taxa groups are not due to artefacts of data selection, small sample size, test procedures, or other reasons unrelated to a specific mode of action?*
   It is unlikely that bimodality or multimodality are being masked through the data selection process as the dataset consists of 20 species representing six taxonomic groups, greater than the 15-species threshold required to be considered 'Preferred' sample size per Warne et al. (2018).

Species Sensitivity Distribution Analysis

Cumulative probability distributions were fit to the available species sensitivity data using ssdtools v2.2.0 (Thorley et al., 2025). **Figure C1** illustrates the distribution of chronic effects data, fit using a model-averaged distribution. The associated EQGs for species protection between 80 to 99 percent are shown in **Table C4**.

The ssdtools approach applies multiple distributions and relies on a model-averaging methodology to obtain a combined predictive model (Thorley et al., 2025). The model-averaging approach aims to minimise bias, estimate reliable protection levels and confidence intervals that are robust to small changes in the data, and provide a set of underlying statistical distributions that balance flexibility, stability, and performance (Fox et al., 2022). Ssdtools software utilizes six different distribution types by default: log-normal, log-logistic, log-Gumbel (inverse Weibull), Gamma, Weibull, and a log-normal mixture. The goodness of fit for each ssdtools distribution applied to the selenium dataset is illustrated in **Figure C2.** The model-averaged result is a weighted average based on the quality of the fit from each of these distributions. Fit quality is assessed using the Akaike information criterion corrected for the underlying sample size (AIC_c) to determine a relative distribution weight. The underlying distribution with the best fit to the data was the log-Gumbel model with a relative weight of 0.594. A summary of the goodness of fit statistics for each distribution comprising the model-averaged fit can be found in **Table C5**. A summary of the the ssdtools outputs for selenium is provided in **Figure C3**.

Recommended Selenium EQG

The data in **Table C3** were used to generate EQGs for LOPs between 80 to 99 percent (**Table C4**) using the SSD approach with the ssdtools v2.2.0 software (Thorley et al., 2025). The current LRV (3 µg/L) derived by the AF method relies on one data point and is intended to be overly cautious.

Determining the Reliability of the EQG

The EQG reliability was determined using criteria that considers, 1) the dataset sample size, 2) the type of data included (chronic, combined chronic and converted acute, or converted acute) and 3) the quality of data fit in the SSD (Warne et al., 2018). Warne et al., 2018 states "Datasets that have 5–7 species are termed 'adequate', datasets that contain data for 8–14 species that belong to at least four taxonomic groups are 'good' and datasets that contain data for at least 15 species belonging to at least four taxonomic groups are termed 'preferred'." The selenium dataset has 20 species included across 6 groups, which classifies in the "preferred" sample size. This dataset includes combined chronic and converted acute data and the fit of the SSD is considered "good". Thus, this EQG is considered moderate reliability.

Bioaccumulation Correction

Finally, selenium is a constituent known to bioaccumulate and bioaccumulation must be considered when deriving EQGs. ANZG (2018) states, "to account for the bioaccumulating nature of this toxicant, it is recommended to apply the species protection level "designated guideline values" (DGV) one level above that which would normally be applied (e.g., if 95 percent level of species protection would normally be applied, then the 99 percent DGV should be used (Warne et al., 2018)." In Cockburn Sound there are areas of high, moderate and low ecological protection. These correspond to 95th, 90th and 80th percent levels of protection, respectively (as defined by ANZECC and ARMCANZ 2000). However, with a constituent that bioaccumulates, 99th, 95th and 85th percent levels of protection are adopted. As selenium is a constituent known to bioaccumulate, the 99th, 95th and 85th percent LOPs are used for the high, moderate and low levels of ecological protection, respectively. It should be acknowledged that this adjustment is a surrogate approach that does not directly consider potential risks to higher order biota which may be exposed through dietary uptake.

It is also worth noting that other jurisdictions incorporate bioaccumulation into EQGs in different ways. For example, the USEPA updated freshwater EQGs for selenium in 2016 with a recommendation that fish tissue toxicity data be given precedence over the water column toxicity data when both types of data are available, because fish tissue concentrations are a more direct measure of selenium bioaccumulation and potential toxicity to aquatic life than water column concentrations alone.

To establish greater confidence in the protectiveness of the derived EQGs for selenium, an additional lines-of-evidence assessment was conducted to directly consider the bioaccumulation pathway in Cockburn Sound (**Attachment D; Attachment E**). This assessment included a qualitative assessment of available site-specific sea star (*Archaster angulatus*) tissue data and quantitative dietary modelling (Presser and Luoma, 2010).

The robust lines-of-evidence assessment revealed two key findings:

1. Selenium tissue concentrations observed in a key invertebrate receptor species (*A. angulatus*) adjacent to the Site do not differ significantly from those observed in background areas over 11 km away, and,
2. Surface water concentrations of selenium associated with adverse effects in waters adjacent to the Site range from 322 µg/L to 726 µg/L.

This means that both the 99th percent species protection level of 9.3 µg/L and the 95th percent species protection level of 31 µg/L generated through the SSD are protective to higher trophic levels and as a site-specific limit, respectively. However, there are acknowledged uncertainties associated with this lines-of-evidence assessment, specifically regarding parameterisation of the quantitative dietary model, that preclude the adoption of the 95th percent species protection level (31 µg/L) derived for Site monitoring efforts at this time. Therefore, the 95th percentile background concentration of 10 µg/L will be adopted as the interim EQG for the purpose of advancing the program noting that further assessment could be required to address outstanding uncertainties and develop a reliable EQG that is protective of receptors in Cockburn Sound.

Comparison to Other Existing Selenium Limits

USEPA updated its freshwater selenium EQG in 2016. The current guidelines only consider chronic toxicity data due to the bioaccumulating nature of the metal. The criteria consider both water column (1.2 µg/L and 3.1 µg/L for lentic and lotic systems respectively) and fish tissue-based criteria (considering tissue concentrations by dry weight (dw)) but recommend that fish tissue toxicity data be given precedence as it is a more direct measure of selenium bioaccumulation. Egg-ovary tissue (limit = 15.8 mg/kg dw) is additionally given precedence over whole body (8.0 mg/kg dw) or muscle tissue (11.3 mg/kg dw).

The ANZG EQG for freshwater selenium, 5 µg/L, was promulgated in 2000 (ANZECC & ARMCANZ, 2000) and was set at the 99 percent LOP due to the bioaccumulating nature of selenium. No other published guidelines for marine selenium toxicity were identified.

Conclusions

The available marine toxicity data for selenium was collated and analysed according to the current guidelines (ANZG, 2018; Warne et al., 2018) for EQG derivation to derive a new moderate reliability guideline. The current LRV for marine total selenium is 3 µg/L. Analysis of contemporised toxicity data for marine selenium allowed for the derivation of EQGs at various LOPs. Guideline values for 99th, 95th, 90th, 85th and 80th percent LOP are 9.3, 31, 53, 76 and 100 µg/L, respectively. To establish greater confidence in the protectiveness of these derived EQGs for selenium, an additional lines-of-evidence assessment was conducted to directly consider the bioaccumulation pathway in Cockburn Sound (**Attachment D; Attachment E**). Due to the acknowledged uncertainties associated with this lines-of-evidence assessment, the 95th percent species protection level (31 µg/L) will not be used for Site monitoring efforts at this time. Instead, the 95th percentile background concentration of 10 µg/L will be adopted as the interim EQG for the purpose of advancing the program noting that further assessment could be required to address outstanding uncertainties and develop a reliable EQG that is protective of receptors in Cockburn Sound.

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Tables

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Karthikeyan et al., 2019		Karthikeyan et al., 2019		Nagarjuna et al., 2018		Nagarjuna et al., 2018	
No.	Question	ANZG scoring criteria	*Longipedia weberi*		*Mysid*		*Penaeus monodon* and *Perna viridis*		*Penaeus monodon* and *Perna viridis*	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 96 h	10	yes, 96 h	10	yes, 96h	10	yes, 21d	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	yes, stated mortality not defined	5	yes, stated mortality not defined	5	yes, stated mortality not defined	5	yes, stated mortality not defined	5
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, LC	5	yes, LC	5	yes, LC50	5	yes, LOEC NOEC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, 50%	5	yes, 50%	5	yes, 50%	5	yes, NOEC/LOEC was qualified by SD	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 3x	5	yes, 3x	5	yes, 3x	5	yes, 2x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred, methods state, "The study followed standard guidelines for conduct of toxicity bioassays on diatoms and copepods for achieving the objective of deriving toxicity values"	2	yes, inferred, methods state, "The study followed standard guidelines for conduct of toxicity bioassays on diatoms and copepods for achieving the objective of deriving toxicity values"	2	yes, inferred: method of Sprague (1971) and Stephan et al. (1985). Stephan =USEPA	2	yes, inferred: method of Sprague (1971) and Stephan et al. (1985). Stephan =USEPA	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	no, just "adult"	0	no, just "adult"	0	yes, 11-14d age (*P.monodon*); yes, 30-35 mm length (*P. viridis*)	5	yes, 11-14d age (*P.monodon*); yes, 30-35 mm length (*P. viridis*)	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, filtered seawater	5	yes, filtered seawater	5	yes, filtered/UV seawater	5	yes, filtered/UV seawater	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, though inferred, static	4	yes, though inferred, static	4	yes, flow through	4	yes, flow through	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, measured beginning and end	4	yes, measured beginning and end	4	yes, acute measured at 24 h intervals	4	yes, chronic 7d intervals	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	no, insufficient information provided to infer if reference toxicity tests were run.	0	no, insufficient information provided to infer if reference toxicity tests were run.	0	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	yes, dose-response curves show a concentration response	4	yes, dose-response curves show a concentration response	4	yes, dose and response percent recovery (table 1) show a toxicant response relationship	4	yes, dose and response percent recovery (table 2) show a toxicant response relationship	4
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, Probit Analysis and Dunnet's method	4	yes, Probit Analysis and Dunnet's method	4	yes, LC50 calculated by Probit Analysis with 95% CL	4	yes, NOEC/LOEC calculated by ANOVA and Dunnet's method	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, SD	4	yes, SD	4	yes, SD	4	no, SD was used as an estimate of variability	0

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

No.	Non-Plant Criteria		Karthikeyan et al., 2019		Karthikeyan et al., 2019		Nagarjuna et al., 2018		Nagarjuna et al., 2018	
	Question	ANZG scoring criteria	*Longipedia weberi*		*Mysid*		*Penaeus monodon* and *Perna viridis*		*Penaeus monodon* and *Perna viridis*	
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 29 ± 1 psu	3	yes, measured and stated: 29 ± 1 psu	3	yes, measured and stated: 29.5 ± 0.3 psu	3	yes, measured and stated: 29.5 ± 0.3 psu	3
16.2	Was dissolved oxygen measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	yes, DO measured and stated: 4.9 ± 0.7 mg/L	3	yes, DO measured and stated: 4.9 ± 0.7 mg/L	3
16.3	Was conductivity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.5	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no, pH measurements not taken	0	no, pH measurements not taken	0	yes, pH measured and stated: 7.9 ± 0.7	3	yes, pH measured and stated: 7.9 ± 0.7	3
16.4	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no, DOC measurements not taken	0	no, DOC measurements not taken	0	no, DOC measurements not taken	0	no, DOC measurements not taken	0
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 24 ± 2 C	3	yes, measured and stated: 24 ± 2 C	3	yes, temp measured and stated: 25 ± 2 C	3	yes, temp measured and stated: 25 ± 2 C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	no, chemical grade not stated; F/2 culture media was as prescribed by OECD guidelines	0	no, chemical grade not stated; F/2 culture media was as prescribed by OECD guidelines	0	no, chemical grade not stated	0	no, chemical grade not stated	0
	Total Score	100		68		68		81		77
	Quality score			68		68		81		77

Non-Plant Criteria			Brix et al., 2004		Brix et al., 2004		Brix et al., 2004		Ward et al., 1981	
No.	Question	ANZG scoring criteria	*Artemia franciscana*		*Ephydra cinerea*		*Artemia franciscana*		*Mysidopsis bahia*	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 96h	10	yes, 96h	10	yes, 28d	10	yes, 96h	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	yes, stated not defined	5	yes, stated not defined	5	yes, stated and defined	10	yes, stated, not defined	5
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, LC, NOEC, LOEC	5	yes, LC, NOEC, LOEC	5	yes, NOEC, LOEC	5	yes, LC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, 50%	5	yes, 50%	5	yes, NOEC/LOEC was qualified by CL	5	yes, 50%	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, GSL water no toxicant control	5	yes, GSL water no toxicant control	5	yes, GSL water no toxicant control	5	yes, seawater no toxicant control	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 4x	5	yes, 4x	5	yes, 16x	5	yes, 4x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred: modeled on Brix et al., 2003, U.S. EPA, and European Union protocols	2	yes, inferred: modeled on Brix et al., 2003, U.S. EPA, and European Union protocols	2	yes, inferred followed methods by the U.S. EPA and European Union	2	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	yes, by age (<24 h)	5	yes, by age (8 weeks)	5	yes, Survival at day 11, 21, 28, growth at days 11, 28, reproduction at 21, 28, F1 Survival, and F1 Growth	5	yes, 4-6 mm total length	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, GSL water	5	yes, GSL water	5	yes, GSL water	5	yes, filtered seawater	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, static	4	yes, static	4	yes, intermittent-flow through	4	yes, intermittent-flow systems	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, mean measured test concentrations were 86 to 98% of nominal with within-treatment coefficients of variation (variability over time) ranging from 10 to 19%.	4	yes, mean measured test concentrations were 86 to 98% of nominal with within-treatment coefficients of variation (variability over time) ranging from 10 to 19%.	4	yes, mean measured test concentrations were 79 to 126% of nominal with within-treatment coefficients of variation ranging from 11 to 20%.	4	yes, measured (>1 time) though methods/quantity for measurement not explicitly stated	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	yes. "well-defined concentration–response relationships were observed for all of the studies"	4	yes. "well-defined concentration–response relationships were observed for all of the studies"	4	yes. "well-defined concentration–response relationships were observed for all of the studies"	4	no	0
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, LC50s and 95%CL: Probit NOEC and LOEC: Steel's many–one rank test	4	yes, LC50s and 95%CL: Probit NOEC and LOEC: Steel's many–one rank test	4	yes, NOEC and LOEC calculated in accordance with procudured described by the EU (15)	4	yes, LC50 and CL: linear regression (Probit, Finney 1971)	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, 95% CL	4	yes, 95% CL	4	yes, 95% CL	4	yes, LC with 95% CL	4

Non-Plant Criteria			Brix et al., 2004		Brix et al., 2004		Brix et al., 2004		Ward et al., 1981	
No.	Question	ANZG scoring criteria	*Artemia franciscana*		*Ephydra cinerea*		*Artemia franciscana*		*Mysidopsis bahia*	
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 80–102 g/L	3	yes, measured and stated: 80–102 g/L	3	yes, measured and stated: 80–102 g/L	3	yes, measured and stated: 30 ppt	3
16.2	Was dissolved oxygen measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 1.8–6.0	3	yes, measured and stated: 1.8–6.0	3	yes, measured and stated: 1.8–6.0	3	no	0
16.3	Was conductivity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.5	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 7.9–8.4	3	yes, measured and stated: 7.9–8.4	3	yes, measured and stated: 7.9–8.4	3	no	0
16.4	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 34.8–40 mg/L	3	yes, measured and stated: 34.8–40 mg/L	3	yes, measured and stated: 34.8–40 mg/L	3	no	0
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 25 ± 1 C	3	yes, measured and stated: 25 ± 1 C	3	yes, measured and stated: 25 ± 1 C	3	yes, measured and stated: 22 ± 1 C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	yes, reagent grade (95%) chemicals used	3	yes, reagent grade (95%) chemicals used	3	yes, reagent grade (95%) chemicals used	3	no, purity of chemicals not stated	0
	Total Score	100		87		87		92		71
	Quality score			87		87		92		71

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Ward et al., 1981		Ward et al., 1981		Ward et al., 1981		Ward et al., 1981	
No.	Question	ANZG scoring criteria	*Cyprinodon variegatus*		*Penaeus aztecus*		*Callinectes sapidus*		*Lagodon rhomboides*	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 96h	10	yes, 96h	10	yes, 96h	10	yes, 96h	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	yes, stated, not defined	5	yes, stated, not defined	5	yes, stated, not defined	5	yes, stated, not defined	5
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, LC	5	yes, LC	5	yes, LC	5	yes, LC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, 50%	5	yes, 50%	5	yes, 50%	5	yes, 50%	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 2x	5	yes, 4x	5	yes, 2x	5	yes, 4x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	yes, 12-16 mm standard length	5	yes, 42-67 mm rostrum-telson length	5	yes, 8-13 mm carapace width	5	yes, 55-73 mm standard length	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, filtered seawater	5	yes, filtered seawater	5	yes, filtered seawater	5	yes, filtered seawater	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, intermittent-flow systems	4	yes, static	4	yes, static	4	yes, static	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, measured: methods/quantity for measurement not explicitly stated	4	yes, measured: methods/quantity for measurement not explicitly stated	4	yes, measured: methods/quantity for measurement not explicitly stated	4	yes, measured: methods/quantity for measurement not explicitly stated	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	no	0	no	0	no	0	no	0
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, LC50 and CL: linear regression (Probit, Finney 1971)	4	yes, LC50 and CL: linear regression (Probit, Finney 1971)	4	yes, LC50 and CL: linear regression (Probit, Finney 1971)	4	yes, LC50 and CL: linear regression (Probit, Finney 1971)	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, LC with 95% CL	4	yes, LC with 95% CL	4	yes, LC with 95% CL	4	yes, LC with 95% CL	4

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Ward et al., 1981		Ward et al., 1981		Ward et al., 1981		Ward et al., 1981	
No.	Question	ANZG scoring criteria	*Cyprinodon variegatus*		*Penaeus aztecus*		*Callinectes sapidus*		*Lagodon rhomboides*	
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 30 ppt	3	yes, measured and stated: 30 ppt	3	yes, measured and stated: 30 ppt	3	yes, measured and stated: 30 ppt	3
16.2	Was dissolved oxygen measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.3	Was conductivity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.5	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.4	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 22 ± 1 C	3	yes, measured and stated: 22 ± 1 C	3	yes, measured and stated: 22 ± 1 C	3	yes, measured and stated: 22 ± 1 C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	no, purity of chemicals not stated	0	no, purity of chemicals not stated	0	no, purity of chemicals not stated	0	no, purity of chemicals not stated	0
	Total Score	100		71		71		71		71
	Quality score			71		71		71		71

Table C1

"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Ward et al., 1981		Ward et al., 1981		Forsythe et al., 1994		Glickstein, 1978	
No.	Question	ANZG scoring criteria	*Mysidopsis bahia* -chronic		*Cyprinodon variegatus* - chronic		*Artemia spp*		*Crassostrea gigas*	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 17d	10	yes, 18-29 d	10	yes, 96h	10	yes, 48h	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	stated and defined: "embryo death was an opaque, white, fungal growth and for the larvae, a white coloration of the trunk musculature (Schimmel 1974)".	10	stated, not defined	5	stated, not defined	5	yes, abnormal development defined as "failure to reach a straight hinged, "D"-shaped veliger"	10
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, MATC	5	yes, MATC	5	yes, LC	5	yes, EC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, p<0.05	5	yes, p<0.05	5	yes, 50%	5	yes, 50%	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5	yes, seawater no toxicant	5	yes, seawater no toxicent	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 2x (Schimmel 1974)	5	yes, 2x (Ward 1981b)	5	yes, 4x	5	yes, 3x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2	yes, inferred: methods followed USEPA "The Committee on Methods for Toxicity Tests with Aquatic Organisms" (1975)	2	yes, inferred, methods reference acceptable criteria Warner et al. (1979)	2	yes, inferred, methods follow Woelke (1972) WA Department of Fisheries Report	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	yes, 2mm length	5	yes, eggs harvested and fertilized in lab	5	yes, less than 24h old larvae	5	yes, fertilized eggs 48h	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, filtered seawater	5	yes, filtered seawater	5	yes, two types: low and high sulfate 0.05 and 14 mg/l	5	yes, filtered seawater	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, intermittent-flow systems	4	yes, intermittent-flow systems	4	yes, static inferred from method description (petri dishes on shaker)	4	yes, static inferred from method description	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, concentrations in test and control water were determined weekly by gas chromatograph (Schimmel 1974).	4	yes, "water samples were taken at the start and end of the tests and analyzed quantitatively for the chemical of interest (Ward, 1981b)"	4	yes, measured: beginning and end (Spectrophotometry)	4	yes, measured atomic absorption spectrophotometry	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2	no	0	yes, inferred, as USEPA methods would require a reference toxicant	2
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	yes, concentration response observable in Table 2 by change in % survival compared to toxicant concentration	4	yes, concentration response observable in Table 2 by change in % survival compared to toxicant concentration	4	yes, concentration response observable in Table 3 by change in % mortality compared to concentration of Se	4	yes, concentration response observable in Table 2 by change in % mortality compared to concentration of Se	4
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, ANOVA, Williams (1971) or Dunnett's (1960)	4	yes, ANOVA, Williams (1971) or Dunnett's (1960)	4	yes, LC50s: Probit and Spearman-Karber trim methods Developmental assays: two-way ANOVAs	4	yes, Student-Newman-Keuls Multiple Range Test (Sokal and Rohlf, 1969)	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, p<0.05	4	yes, p<0.05	4	no	0	yes, ± 1SD	4

EHS Support

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		**Ward et al., 1981**		**Ward et al., 1981**		**Forsythe et al., 1994**		**Glickstein, 1978**	
No.	**Question**	**ANZG scoring criteria**	***Mysidopsis bahia* -chronic**		***Cyprinodon variegatus* - chronic**		***Artemia spp***		***Crassostrea gigas***	
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 26 ± 2%	3	yes, measured and stated: 27 ± 2%	3	yes, stated and measured at beginning only: 36.292 ppt	3	yes, measured and stated: 33.79 ± 0.07%	3
16.2	Was dissolved oxygen measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	yes, measured and stated: 6.5 to 8.0 mg/L	3
16.3	Was conductivity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.5	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	yes, measured and stated: 8.1 ± 0.2	3
16.4	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 23 ± 1 C	3	yes, measured and stated: 29 ± 1 C	3	yes, measured and stated: 25 ± 1 C	3	yes, measured and stated: 20 ± 1 C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	no, purity of chemicals not stated	0	no, purity of chemicals not stated	0	no, purity of chemicals not stated	0	yes, analytical grade reagents	3
	Total Score	100		80		75		69		89
	Quality score			80		75		69		89

Table C1

"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		**Glickstein, 1978**		**Nelson et al., 1988**		**Nelson et al., 1988**		**Martin et al., 1981**	
No.	**Question**	**ANZG scoring criteria**	***Cancer magister***		***Argopecten irradians***		***Spisula solidissima***		***Crassostrea gigas***	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 48 and 96h	10	yes, 96h	10	yes, 96h	10	yes, 96h	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	yes, stated and defined "opaque, non-motile individual was the criterion for a lethal response"	10	stated, not defined	5	stated, not defined	5	yes, stated and defined as "Larvae which failed to transform to the shelled, hinged 'D' shaped veliger constituted the 'abnormal' criterion"	10
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, LC	5	yes, LC	5	yes, LC	5	yes, EC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, 50%	5	yes, 50%	5	yes, 50%	5	yes, 50%	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, seawater no toxicant	5	yes, control not defined	5	yes, control not defined	5	yes, control not defined	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 4x	5	yes, 3x	5	yes, 2x	5	yes, 3x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred, methods follow Woelke (1972) WA Department of Fisheries Report	2	no other method referenced	0	no other method referenced	0	yes, inferred	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	yes, zoea within 12h of release from egg membrane	5	yes, 21.2 mm shell height (range 17.3-24.5 mm)	5	yes, 15.9 mm length (range 8.9-20.0 mm)	5	yes, larve by age 3-5 weeks	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, filtered seawater	5	yes, filtered seawater	5	yes, filtered seawater	5	yes, filtered and UV treated seawater	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, static inferred from method description	4	yes, static	4	yes, static	4	yes, static	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, measured atomic absorption spectrophotometry	4	no, contaminant measurements/nominal amount not stated	0	no, contaminant measurements nominal amount not stated	0	yes, measured once not stated	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	yes, inferred, as USEPA methods would require a reference toxicant	2	no guiding methodology referenced, cannot determine if reference toxicant testing was conducted	0	no guiding methodology referenced, cannot determine if reference toxicant testing was conducted	0	no guiding methodology referenced, cannot determine if reference toxicant testing was conducted	0
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	yes, concentration response observable in Table 3 by change in % mortality compared to concentration of Se	4	no table/figure/prose to determine concentration-response	0	no table/figure/prose to determine concentration-response	0	no table/figure/prose to determine concentration-response	0
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, Student-Newman-Keuls Multiple Range Test (Sokal and Rohlf, 1969)	4	yes, LC50 and 95% CL: Litchfield and Wilcoxon (1949)	4	yes, LC50 and 95% CL: Litchfield and Wilcoxon (1949)	4	yes, LC50s and EC50s based on Woelke (1972), using probit analysis (Finney, 1971)	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, ± 1SD	4	yes, 95 CL	4	yes, 95 CL	4	yes, 95% CL	4

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Glickstein, 1978		Nelson et al., 1988		Nelson et al., 1988		Martin et al., 1981	
No.	Question	ANZG scoring criteria	*Cancer magister*		*Argopecten irradians*		*Spisula solidissima*		*Crassostrea gigas*	
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 33.79 ± 0.07%	3	yes, measured and stated: 25 ± 2%	3	yes, measured and stated: 25 ± 2%	3	yes, measured and stated: 33.79 ± 0.07%	3
16.2	Was dissolved oxygen measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 6.5 to 8.0 mg/L	3	no	0	no	0	yes, measured and stated: 6.5 to 8.0 mg/L	3
16.3	Was conductivity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
16.5	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated:8.1 ± 0.2	3	yes, measured and stated: 6.9-7.5	3	yes, measured and stated: 6.9-7.5	3	yes, measured and stated: 8.1 ± 0.2	3
16.4	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	no	0	no	0
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 15 ± 1 C	3	yes, measured and stated: 20 ± 2°C	3	yes, measured and stated: 20 ± 2°C	3	yes, measured and stated: 20 ± 1C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	yes, analytical grade reagents	3	no, chemical grade not stated	0	no, chemical grade not stated	0	yes, analytical grade (99%), background concentrations of trace metals measured at the beginning of experiment	3
	Total Score	100		89		66		66		83
	Quality score			89		66		66		83

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Martin et al., 1981		Martin et al., 1981	
No.	Question	ANZG scoring criteria	*Mytilus edulis*		*Cancer magister*	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 96h	10	yes, 96h	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	yes, stated and defined as "Larvae which failed to transform to the shelled, hinged 'D' shaped veliger constituted the 'abnormal' criterion"	10	yes, stated and defined as "an opaque, non-motile individual"	10
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, EC	5	yes, EC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, 50%	5	yes, 50%	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, control not defined	5	yes, control not defined	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 3x	5	yes, 3x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred	2	yes, inferred	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	yes, embryos by age 48 h	5	yes, zoea 12h	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, filtered and UV treated seawater	5	yes, filtered and UV treated seawater	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, static	4	yes, static	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, measured once not stated	4	yes, measured once not stated	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	no guiding methodology referenced, cannot determine if reference toxicant testing was conducted	0	no guiding methodology referenced, cannot determine if reference toxicant testing was conducted	0
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	no table/figure/prose to determine concentration-response	0	no table/figure/prose to determine concentration-response	0
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, LC50s and EC50s based on Woelke (1972), using probit analysis (Finney, 1971)	4	yes, LC50s and EC50s based on Woelke (1972), using probit analysis (Finney, 1971)	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, 95% CL	4	yes, 95% CL	4

Table C1
"Non-Plant" Selenium Toxicity Data included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

	Non-Plant Criteria		Martin et al., 1981		Martin et al., 1981	
No.	Question	ANZG scoring criteria	*Mytilus edulis*		*Cancer magister*	
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 33.79 ± 0.07%	3	yes, measured and stated: 33.79 ± 0.07%	3
16.2	Was dissolved oxygen measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 6.5 to 8.0 mg/L	3	yes, measured and stated: 6.5 to 8.0 mg/L	3
16.3	Was conductivity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0
16.5	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 8.1 ± 0.2	3	yes, measured and stated: 8.1 ± 0.2	3
16.4	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 20 ± 1C	3	yes, measured and stated: 20 ± 1C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	yes, analytical grade (99%), background concentrations of trace metals measured at the beginning of experiment	3	yes, analytical grade (99%), background concentrations of trace metals measured at the beginning of experiment	3
	Total Score	100		83		83
	Quality score			83		83

Notes:

ANOVA = analysis of variance
ASTM = American Society for Testing and Materials
C = degrees Celcius
CL = confidence limits
d = days
DOC = dissolved organic carbon
EC = effect concentration
EU = European Union
g/L = grams per litre
GSL = Great Salt Lake
h = hours
IC = inhibitory concentration
LC = lethal concentration
LOEC = lowest observed effect concentration
MATC = maximum acceptable toxicant concentration
mg/l = milligrams per litre
mm = millimeters
NOEC = no effect concentration
OECD = Organisation for Economic Co-operation and Development
ppt = parts per thousand
psu = practical salinity unit
SD = standard deviation
temp = temperature
USEPA = United States Environmental Protection Agency
UV = ultraviolet

Table C2
Plant Selenium Toxicity Data Included in SSD Analysis and Quality Scoring
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Plant Criteria			Karthikeyan et al., 2019		Karthikeyan et al., 2019		Brix et al., 2004		Brix et al., 2004	
No.	**Question**	**ANZG scoring criteria**	*Dontella mobiliensis*		*Skeletonema costatum*		*Dunaliella viridis* - acute		*Dunaliella viridis* - chronic	
1	Was the duration of the exposure stated?	Yes (10), No (0)	yes, 96 h	10	yes, 96 h	10	yes, 96h	10	yes, 96h	10
2	Was the biological endpoint stated and defined?	Yes (10), Stated only (5), Neither (0)	yes, growth rate	10	yes, growth rate	10	yes, stated not defined	5	yes, stated not defined	5
3	Was the biological effect stated (for example, LC or NOEC)?	Yes (5), No (0)	yes, IC	5	yes, IC	5	yes, EC, NOEC, LOEC	5	yes, NOEC, LOEC	5
4	Was the biological effect quantified (for example 50% effect, 25% effect). The effect for NOEC and LOEC data must be quantified.	Yes (5), No (0)	yes, 50%	5	yes, 50%	5	yes, 50%	5	yes, NOEC/LOEC was qualified by CL	5
5	Were appropriate controls (for example a no- toxicant control and/or solvent control) used?	Yes (5), No (0)	yes, seawater no toxicant control	5	yes, seawater no toxicant control	5	yes, GSL water no toxicant control	5	yes, GSL water no toxicant control	5
6	Was each control and chemical concentration at least duplicated?	Yes (5), No (0)	yes, 3x	5	yes, 3x	5	yes, 4x	5	yes, 4x	5
7	Were test acceptability criteria stated or inferred (for example mortality in controls must not exceed a certain percentage)? Data that fail the acceptability criteria are automatically deems to be of unacceptable quality and must not be used.	Stated (5), Inferred (2), Neither (0)	yes, inferred, methods state, "The study followed standard guidelines for conduct of toxicity bioassays on diatoms and copepods for achieving the objective of deriving toxicity values"	2	yes, inferred, methods state, "The study followed standard guidelines for conduct of toxicity bioassays on diatoms and copepods for achieving the objective of deriving toxicity values"	2	yes, inferred: modeled on Brix et al., 2003, U.S. EPA, and European Union protocols	2	yes, inferred: modeled on Brix et al., 2003, U.S. EPA, and European Union protocols	2
8	Were the characteristics of the test organism (for example length, mass, age) stated?	Yes (5), No (0)	yes, created linear growth rate	5	yes, created linear growth rate	5	yes, log-phase growth	5	yes, log-phase growth	5
9	Was the type of test media used stated?	Yes (5), No (0)	yes, filtered/UV seawater enriched with F/2 media	5	yes, filtered/UV seawater enriched with F/2 media	5	yes, GSL water	5	yes, GSL water	5
10	Was the type of exposure (for example static, flow-through) stated?	Yes (4), No (0)	yes, though inferred, static	4	yes, though inferred, static	4	yes, static	4	yes, static	4
11	Were the contaminant concentrations measured at the beginning and end of the exposure? Note: Normally, toxicity data calculated using nominal concentration data would not be used to derive GVs; however, professional judgement can be used to include such data, provided a justification for their use is provided.	Yes (4), Measured once (2), Not measured or stated (0)	yes, measured beginning and end	4	yes, measured beginning and end	4	yes, mean measured test concentrations were 86 to 98% of nominal with within-treatment coefficients of variation (variability over time) ranging from 10 to 19%.	4	yes, "In the chronic *D. viridis* study, mean measured test concentrations were 67 to 70% of nominal with within-treatment coefficients of variation ranging from 4 to 7%."	4
12	Were parallel reference toxicant toxicity tests conducted?	Yes (4), No (0)	no, insufficient information provided to infer if reference toxicity tests were run.	0	no, insufficient information provided to infer if reference toxicity tests were run.	0	yes, inferred, as USEPA methods would require a reference toxicant	2	yes, inferred, as USEPA methods would require a reference toxicant	2
13	Was there a concentration-response relationship either observed or stated?	Yes (4), No (0)	yes, dose-response curves show a concentration response	4	yes, dose-response curves show a concentration response	4	yes. "well-defined concentration–response relationships were observed for all of the studies"	4	yes. "well-defined concentration–response relationships were observed for all of the studies"	4
14	Was an appropriate statistical method or model used to determine the toxicity? Note: They should be accepted by a recognised national or international regulatory body (for example USEPA, OECD and ASTM)	Yes (4), No (0)	yes, Probit Analysis and Dunnet's method	4	yes, Probit Analysis and Dunnet's method	4	yes, LC50s and 95%CL: Probit NOEC and LOEC: Steel's many-one rank test	4	yes, LC50s and 95%CL: Probit NOEC and LOEC: Steel's many-one rank test	4
15	For LC/EC/NEC/BEC data, was an estimate of variability provided? For NOEC/LOEC/MDEC/MATC data, was the significance level 0.05 or less?	Yes (4), No (0)	yes, SD	4	yes, SD	4	yes, 95% CL	4	yes, 95% CL	4
16.1	Was conductivity/salinity measured at least at the beginning and end of the toxicity test and values stated?	Measured and stated (3), Measured only (1), Neither (0)	yes, measured and stated: 29 ± 1 psu	3	yes, measured and stated: 29 ± 1 psu	3	yes, measured and stated: 80–102 g/L	3	yes, measured and stated: 80–102 g/L	3
16.2	Was pH measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	yes, measured and stated: 7.9–8.4	3	yes, measured and stated: 7.9–8.4	3

Table C2

Plant Selenium Toxicity Data Included in SSD Analysis and Quality Scoring

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

	Plant Criteria		Karthikeyan et al., 2019		Karthikeyan et al., 2019		Brix et al., 2004		Brix et al., 2004	
No.	**Question**	**ANZG scoring criteria**	*Dontella mobiliensis*		*Skeletonema costatum*		*Dunaliella viridis* - acute		*Dunaliella viridis* - chronic	
16.3	Was dissolved organic carbon measured at least at the beginning and end of the toxicity test?	Measured and stated (3), Measured only (1), Neither (0)	no	0	no	0	yes, measured and stated: 34.8–40 mg/L	3	yes, measured and stated: 34.8–40 mg/L	3
17	Was the temperature measured and stated?	Measured and stated (3), Measured but not stated or temperature of the room or chamber was stated (1), Neither (0)	yes, measured and stated: 24 ± 2 C	3	yes, measured and stated: 24 ± 2 C	3	yes, measured and stated: 25 ± 1 C	3	yes, measured and stated: 25 ± 1 C	3
18	Were test solutions, blanks and/or controls tested for contamination or were analytical reagent grade chemicals or the highest possible purity chemicals used for the experiment?	Yes (3), No (0)	no, chemical grade not stated; F/2 culture media was as prescribed by OECD guidelines	0	no, chemical grade not stated; F/2 culture media was as prescribed by OECD guidelines	0	yes, reagent grade (95%) chemicals used	3	yes, reagent grade (95%) chemicals used	3
	Total Score	94		78		78		84		84
	Quality score			83		83		89		89

Notes:

C = degrees Celcius
CL = confidence limits
EC = effect concentration
g/L = grams per litre
GSL = Great Salt Lake
h = hours
IC = inhibitory concentration
LOEC = lowest observed effect concentration
NOEC = no effect concentration
OECD = Organisation for Economic Co-operation and Development
psu = practical salinity unit
SD = standard deviation
US EPA = United Staes Environmental Protection Agency
UV = ultraviolet

Table C3
Selenium Toxicity Data Included in SSD
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Phyla	Scientific Name	Common Name	Life Stage	Relevant Endpoints	Duration	Duration Unit	Chronic Value Approach	Toxicity Measure (µg/L)	Notes	Citation
crustacean	*Artemia franciscana*	brine shrimp	larvae	reproduction—parental day 28	28	d	Reported Chronic NOEC	15000	c	Brix et al., 2004
	Artemia spp.	brine shrimp	larvae	survival	96	h	ACR Converted Acute LC50	517	a	Forsythe et al., 1994
	Callinectes sapidus	blue crabs	juvenile	survival	96	h	ACR Converted Acute LC50	398		Ward et al., 1981
	Cancer magister	dungeness crab	larvae	survival	48	h	ACR Converted Acute LC50	90	b	Glickstein, 1978
	Longipedia weberi	copepod	adult	growth, survival	96	h	ACR Converted Acute LC50	84		Karthikeyan et al., 2019
	Mysid	mysid shrimp	adult	growth, survival	96	h	ACR Converted Acute LC50	98		Karthikeyan et al., 2019
	Mysidopsis bahia	mysid shrimp	subadult	survival, growth, reproduction	17	d	Reported Chronic NOEC	140	c	Ward et al., 1981
	Penaeus aztecus	brown shrimp	subadult	survival	96	h	ACR Converted Acute LC50	104		Ward et al., 1981
	Penaeus monodon	giant tiger shrimp	post larvae	survival	21	d	Reported Chronic NOEC	80	c	Nagarjuna et al., 2018
diatom	*Odontella mobiliensis*	diatom	NA	growth	96	h	Reported Chronic NOEC	1170		Karthikeyan et al., 2019
	Skeletonema costatum	diatom	NA	growth	96	h	Reported Chronic NOEC	540		Karthikeyan et al., 2019
fish	*Cyprinodon variegatus*	sheepshead minnow	juvenile	survival, growth, reproduction	18	d	Reported Chronic NOEC	470	c	Ward et al., 1981
	Lagodon rhomboides	pinfish	subadult	survival	96	h	ACR Converted Acute LC50	401		Ward et al., 1981
plant	*Dunaliella viridis*	hypersaline alga	NA	growth, survival	28	d	Reported Chronic NOEC	11000		Brix et al., 2004
insect	*Ephydra cinerea*	brine fly	larvae	survival, growth, reproduction	96	h	ACR Converted Acute LC50	54592		Brix et al., 2004
mollusc	*Argopecten irradians*	bay scallops	juvenile	survival	96	h	ACR Converted Acute LC50	20		Nelson et al., 1988
	Crassostrea gigas	pacific oyster	embryos	abnormal development	48	h	Converted Chronic EC10	1244	c	Martin et al., 1981; Glickstein, 1978
	Mytilus edulis	bay mussel	embryos	abnormal development	48	h	Converted Chronic EC10	1423	c	Martin et al., 1981
	Perna viridis	green mussel	post larvae	survival	30	d	Reported Chronic NOEC	2270	c	Nagarjuna et al., 2018
	Spisula solidissima	surf clams	juvenile	survival	96	h	ACR Converted Acute LC50	212		Nelson et al., 1988

Notes:

µg/L = micrograms per liter

a = geometric mean of toxicity values with the same test conditions and endpoint for a single species.

ACR = acute to chronic ratio

b = the minimum toxicity value from different durations of a single species was used

c = reported chronic data were used

d = days

h = hours

LC50 = median lethal concentration

LOEC = lowest observed effect concentration

NOEC = no effect concentration

Table C4

Marine Selenium Water Quality Guidelines (± CI) Derived Using SSD Approach

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Cockburn Sound Level of Ecological Protection	Level of protection (%)	Guideline Value (µg/L)	95% CL lower	95% CL upper
High	99	9.3	0.791	50.8
Moderate	95	31	6.51	92.8
--	90	53	17.2	138
Low	85	76	29.3	192
--	80	100	44.8	249

Notes:

All guideline values have been rounded to two significant digits per Section 3.6 of Warne et al., (2018).

95% confidence limits were calculated using the parametric bootstrapping technique (n = 10,000) in ssdtools v2.2.0.

CL = confidence limits

µg/L = micrograms per liter

Table C5

ssdtools goodness of fit statistics

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Distribution	Anderson-Darling statistic	Kolmogorov-Smirnov statistic	Cramer-von Mises statistic	Akaike's Information Criterion (AIC)	Sample Size Corrected AIC (AICc)	Bayesian Information Criterion (BIC)	AICc difference	Akaike weight
log-Gumbel (inverse Weibull)	0.266	0.107	0.038	336	337	338	0	0.594
log-normal	0.496	0.147	0.0745	338	339	340	2.23	0.195
log-logistic	0.405	0.121	0.049	338	339	340	2.32	0.187
log-normal mixture	0.283	0.117	0.044	340	344	345	7.33	0.015
Weibull	1.01	0.187	0.169	345	345	347	8.6	0.008
Gamma	1.93	0.275	0.388	351	352	353	14.7	0

Figures

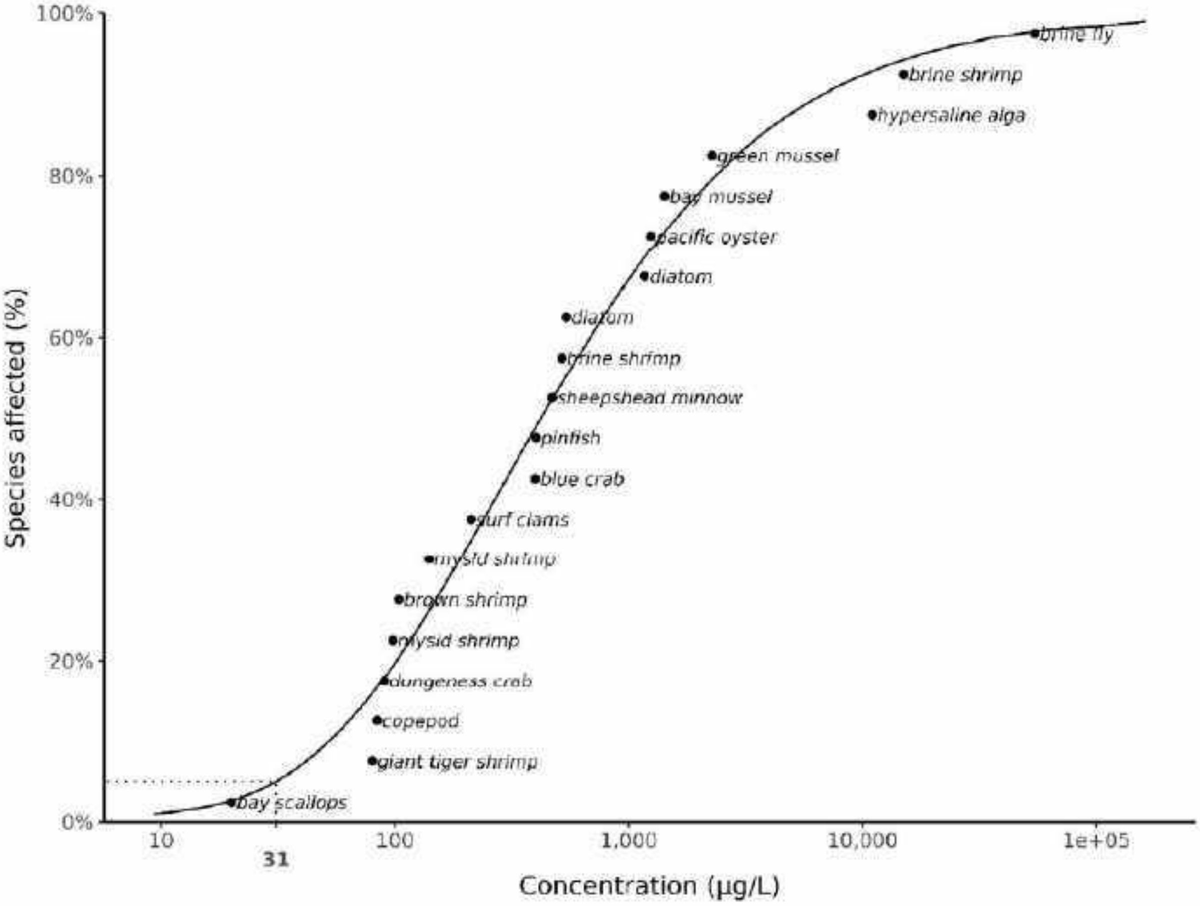


FIGURE C1 - SPECIES SENSITIVITY DISTRIBUTION FOR MARINE SELENIUM ECOTOXICITY DATA

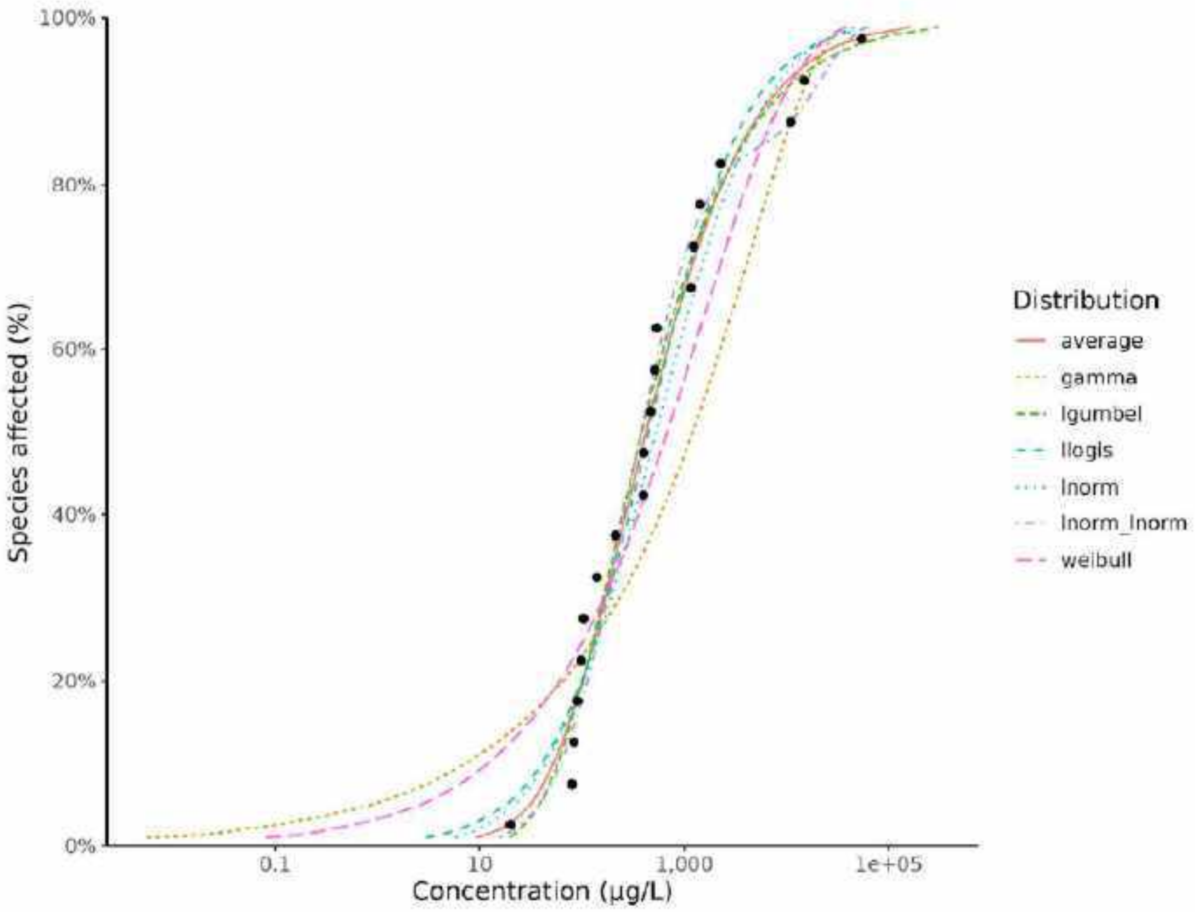


FIGURE C2 - SSDTOOLS GOODNESS OF FIT SUMMARY FOR MARINE SELENIUM ECOTOXICITY DATA

ssdtools v2.2.0 Output

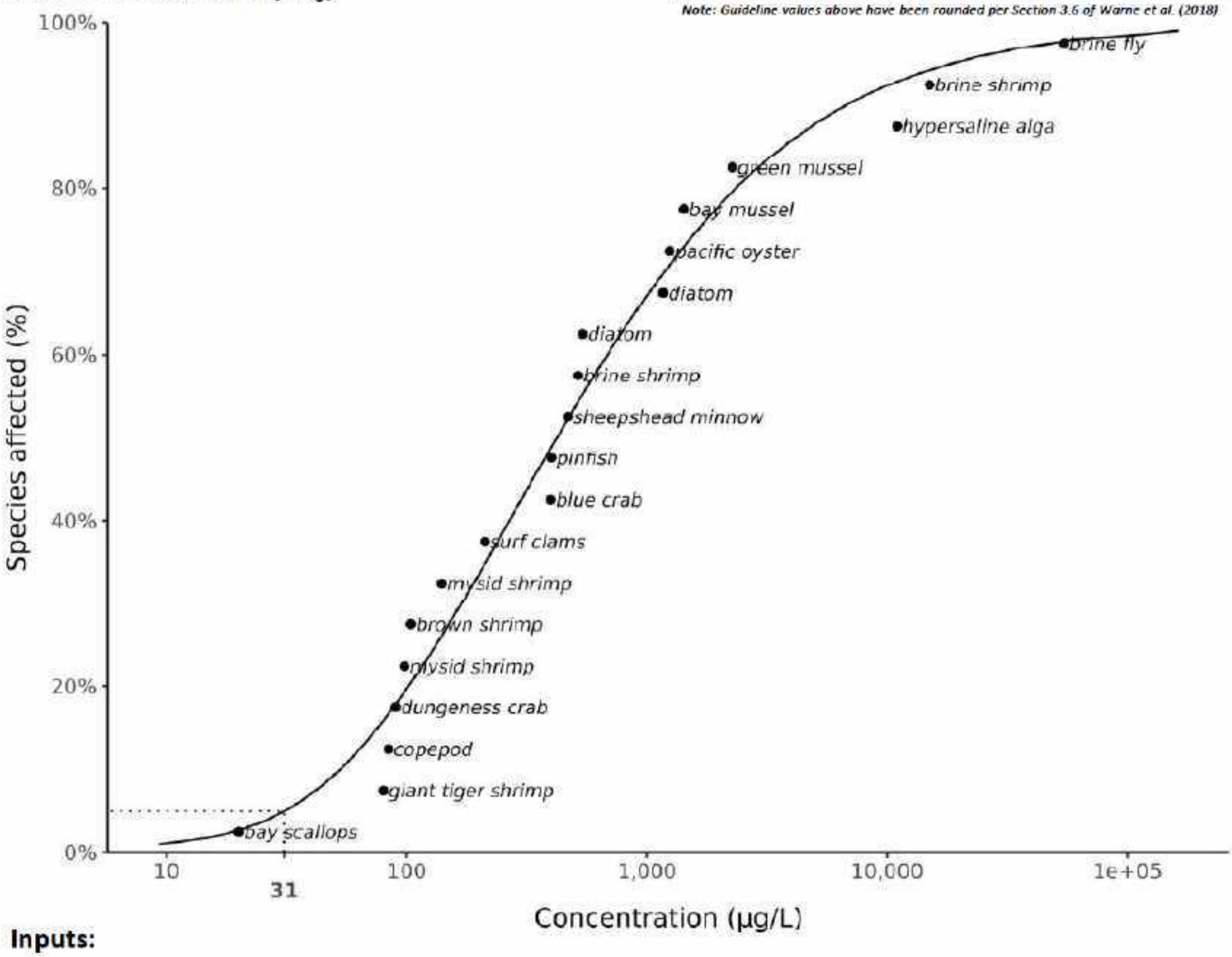
Toxicant: Selenium

Units: micrograms per litre

Protection Level	Guideline Value (CI)
99%	9.3 (0.791, 50.8)
95%	31 (6.51, 92.8)
90%	53 (17.2, 138)
85%	76 (29.3, 192)
80%	100 (44.8, 249)

Note: Guideline values above have been rounded per Section 3.6 of Warne et al. (2018)

95% Protection Level (HC_5):



Inputs:

Phyle	Scientific Name	Common Name	Toxicity Measure (µg/L)
Crustacean	*Artemia franciscana*	Brine Shrimp	15000
	Artemia spp	Brine Shrimp	517
	Callinectes sapidus	Blue Crab	398
	Cancer magister	Dungeness Crab	90
	Longipedia weberi	Copepod	84
	Mysid	Mysid Shrimp	98
	Mysidopsis bahia	Mysid Shrimp	140
	Penaeus aztecus	Brown Shrimp	104
	Penaeus monodon	Giant Tiger Shrimp	80
Diatom	*Odontella mobiliensis*	Diatom	1170
	Skeletonema	Diatom	540
Fish	*Cyprinodon variegatus*	Sheepshead Minnow	470
	Lagodon rhomboides	Pinfish	401
Plant	*Dunaliella viridis*	Hypersaline Algae	11000

Phyla	Scientific Name	Common Name	Toxicity Measure (µg/L)
Insect	*Ephydra cinerea*	Brine Fly	54592
Mollusc	*Argopecten irradians*	Bay Scallops	20
	Crassostrea gigas	Pacific Oyster	1244
	Mytilus edulis	Bay Mussel	1423
	Perna viridis	Green Mussel	2270
	Spisula solidissima	Surf Clams	212

Attachment D Assessment of Available Tissue Data

Attachment D Assessment of Available Tissue Data

Introduction

This assessment was prepared in response to the comment letter received from the Auditor's Supporting Expert Team (SET) on 21 January 2025 regarding the *Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound – EQG Identification and Derivation for Low Reliability Values of Select Metals* ("2024 Derivation Memo") prepared by EHS Support LLC. (EHS Support) dated 26 March 2024. The 2024 Derivation Memo specifically sought to incorporate contemporised marine toxicity data and the most current guidelines (Warne et al., 2018) to derive EQGs that would replace low reliability values for select metals in Cockburn Sound. Cockburn Sound is a 100 km^2 tidal inlet of the Indian Ocean, which is adjacent to the Alcoa Kwinana Refinery located on Hogg Road, Naval Base, Western Australia 6165 (Lot 102 on Parcel 18242, "Site").

In the comment letter, the SET emphasized that while the EQG derivation approach enacted for bioaccumulative constituents (e.g., mercury, cadmium, and selenium) is consistent with the methodology of Warne et al., (2018), there would be greater confidence in the protectiveness of EQGs if an additional, qualitative lines-of-evidence assessment were conducted to understand the bioaccumulative pathway. For toxicants or constituents where bioaccumulation and secondary poisoning effects should be considered, ANZG (2018) states, "to account for the bioaccumulating nature of this toxicant, it is recommended to apply the species protection level default water quality guideline one level above that which would normally be applied (e.g. if 95 percent level of species protection would normally be applied, then the 99 percent default water quality guideline should be used (Warne et al., 2018)." However, this approach is considered an indirect, surrogate assessment of bioaccumulative toxicity that indirectly accounts for toxic effects whilst maintaining a species protection level consistent with the beneficial uses of the waterway. Therefore, an evaluation of available site-specific tissue data for the sea star (*Archaster angulatus*) has been prepared to review tissue concentrations of bioaccumulative metals (i.e., cadmium, mercury, and selenium) adjacent to the Site relative to the background. This information is used to qualitatively evaluate potential risks to higher-order wildlife in Cockburn Sound.

Methods

Site-specific biota tissue collection is reported as a component of the 2007 and 2012 Oceanica Nearshore Survey Data Reports (Oceanica, 2007; 2012), which were completed to maintain an ongoing database of sediment, water quality, biota tissue, and fauna and flora assemblage data in Cockburn Sound. During the two nearshore survey sampling events, five sea stars (*Archaster angulatus*) were collected from three separate sampling locations approximately 40 m from the shoreline (T1, T5, T7). Sampling locations were considered representative of the main area of groundwater discharge into the marine environment (Oceanica, 2012). Two of the sampling sites (T1 and T5) were located adjacent to the Site, while the third sampling site (T7) was located approximately 11 km north at Robb Jetty in Owen Anchorage. Due to the spatial separation, T7 was designated as the representative background location (**Figure D1**). After collection, *A. angulatus* were individually homogenised and subsequently analysed for trace metals. A summary of the available *A. angulatus* tissue dataset for cadmium, mercury, and selenium is provided in **Table D1**.

Cadmium, mercury, and selenium concentrations in *A. angulatus* tissue were evaluated using a one-way analysis of variance (ANOVA) to identify significant differences between concentrations relative to their sample locations. An ANOVA compares the mean tissue concentrations between different sampling locations by analysing the variance within groups and comparatively assessing the variance between groups. A statistically significant result ($p < 0.05$) would indicate that there are differences in mean tissue metal concentrations between *A. angulatus* collected from different sampling locations. Prior to running the ANOVA, analyte concentrations were log-transformed to fit the normality assumption of the analysis.

Results

Analysis results indicate that there are no statistically significant ($p < 0.05$) differences in mean concentrations for cadmium ($p = 0.55$), mercury ($p = 0.68$) or selenium ($p = 0.50$) between sampling locations. These results demonstrate that tissue concentrations are similar between sampling locations adjacent to the Site and in the background. Summary statistics for the evaluated bioaccumulative metals in *A. angulatus* tissue samples are provided below in **Table D2** and ANOVA results are provided in **Table D3.**

Summary

This assessment was conducted to establish greater confidence in the protectiveness of EQGs for three bioaccumulative metals (cadmium, mercury, or selenium) through a qualitative evaluation of available biota tissue data. The results of this assessment suggest that there is no statistically significant increase in the bioaccumulation of the evaluated metals in *A. angulatus* tissues adjacent to Site relative to the background. This qualitative assessment provides important information about potential risks to higher-order wildlife and suggests there is no increased ecological risk of bioaccumulative metals exposure with proximity to the Site. An additional quantitative evaluation of dietary pathways is provided for selenium (**Attachment E**) to account for site-specific food web dynamics and to substantiate these conclusions.

References

ANZG (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

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Oceanica. (2012). Alcoa Nearshore Survey 2011 Data Report. June 2012.

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Warne, MStJ, Batley, GE, van Dam, RA, Chapman JC, Fox DR, Hickey CW, and Stauber JL (2018). Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants, Australian Government Department of Agriculture and Water Resources, Canberra.

Tables

Table D1
Summary of Available Sea Star Tissue Data for Select Bioaccumulative Metals
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Transect	Analyte	Result (mg/kg)	Result Basis	Method	Detected Result (Y/N)	Sample Collection Year	Source Report
T1_40A	Cadmium	0.07	wet	NT2_46	Y	2011	Oceanica 2012
T1_40B	Cadmium	0.09	wet	NT2_46	Y	2011	Oceanica 2012
T1_40C	Cadmium	0.13	wet	NT2_46	Y	2011	Oceanica 2012
T1_40D	Cadmium	0.04	wet	NT2_46	Y	2011	Oceanica 2012
T1_40E	Cadmium	0.07	wet	NT2_46	Y	2011	Oceanica 2012
T5_40A	Cadmium	0.08	wet	NT2_46	Y	2011	Oceanica 2012
T5_40B	Cadmium	0.08	wet	NT2_46	Y	2011	Oceanica 2012
T5_40C	Cadmium	0.22	wet	NT2_46	Y	2011	Oceanica 2012
T5_40D	Cadmium	0.14	wet	NT2_46	Y	2011	Oceanica 2012
T5_40E	Cadmium	0.08	wet	NT2_46	Y	2011	Oceanica 2012
T7_40A	Cadmium	0.18	wet	NT2_46	Y	2011	Oceanica 2012
T7_40B	Cadmium	0.13	wet	NT2_46	Y	2011	Oceanica 2012
T7_40C	Cadmium	0.15	wet	NT2_46	Y	2011	Oceanica 2012
T7_40D	Cadmium	0.12	wet	NT2_46	Y	2011	Oceanica 2012
T7_40E	Cadmium	0.11	wet	NT2_46	Y	2011	Oceanica 2012
T1_A	Cadmium	0.05	--	NT2_46	Y	2006	Oceanica 2007
T1_B	Cadmium	0.12	--	NT2_46	Y	2006	Oceanica 2007
T1_C	Cadmium	0.09	--	NT2_46	Y	2006	Oceanica 2007
T1_D	Cadmium	0.14	--	NT2_46	Y	2006	Oceanica 2007
T1_E	Cadmium	0.1	--	NT2_46	Y	2006	Oceanica 2007
T5_A	Cadmium	0.25	--	NT2_46	Y	2006	Oceanica 2007
T5_B	Cadmium	0.05	--	NT2_46	Y	2006	Oceanica 2007
T5_C	Cadmium	0.04	--	NT2_46	Y	2006	Oceanica 2007
T5_D	Cadmium	0.12	--	NT2_46	Y	2006	Oceanica 2007
T5_E	Cadmium	0.04	--	NT2_46	Y	2006	Oceanica 2007
T7_A	Cadmium	0.07	--	NT2_46	Y	2006	Oceanica 2007
T7_B	Cadmium	0.07	--	NT2_46	Y	2006	Oceanica 2007
T7_C	Cadmium	0.07	--	NT2_46	Y	2006	Oceanica 2007
T7_D	Cadmium	0.15	--	NT2_46	Y	2006	Oceanica 2007
T7_E	Cadmium	0.08	--	NT2_46	Y	2006	Oceanica 2007
T1_40A	Mercury	0.1	wet	NT2_46	Y	2011	Oceanica 2012
T1_40B	Mercury	0.09	wet	NT2_46	Y	2011	Oceanica 2012
T1_40C	Mercury	0.11	wet	NT2_46	Y	2011	Oceanica 2012
T1_40D	Mercury	0.04	wet	NT2_46	Y	2011	Oceanica 2012
T1_40E	Mercury	0.08	wet	NT2_46	Y	2011	Oceanica 2012
T5_40A	Mercury	0.11	wet	NT2_46	Y	2011	Oceanica 2012
T5_40B	Mercury	0.06	wet	NT2_46	Y	2011	Oceanica 2012
T5_40C	Mercury	0.07	wet	NT2_46	Y	2011	Oceanica 2012
T5_40D	Mercury	0.1	wet	NT2_46	Y	2011	Oceanica 2012
T5_40E	Mercury	0.1	wet	NT2_46	Y	2011	Oceanica 2012
T7_40A	Mercury	0.15	wet	NT2_46	Y	2011	Oceanica 2012
T7_40B	Mercury	0.06	wet	NT2_46	Y	2011	Oceanica 2012
T7_40C	Mercury	0.09	wet	NT2_46	Y	2011	Oceanica 2012
T7_40D	Mercury	0.07	wet	NT2_46	Y	2011	Oceanica 2012
T7_40E	Mercury	0.09	wet	NT2_46	Y	2011	Oceanica 2012
T1_A	Mercury	0.04	--	NT2_46	Y	2006	Oceanica 2007
T1_B	Mercury	0.04	--	NT2_46	Y	2006	Oceanica 2007
T1_C	Mercury	0.04	--	NT2_46	Y	2006	Oceanica 2007
T1_D	Mercury	0.05	--	NT2_46	Y	2006	Oceanica 2007

Table D1
Summary of Available Sea Star Tissue Data for Select Bioaccumulative Metals
EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound
Alcoa Kwinana Refinery - Kwinana, Western Australia

Transect	Analyte	Result (mg/kg)	Result Basis	Method	Detected Result (Y/N)	Sample Collection Year	Source Report
T1_E	Mercury	0.08	--	NT2_46	Y	2006	Oceanica 2007
T5_A	Mercury	0.08	--	NT2_46	Y	2006	Oceanica 2007
T5_B	Mercury	0.02	--	NT2_46	Y	2006	Oceanica 2007
T5_C	Mercury	0.03	--	NT2_46	Y	2006	Oceanica 2007
T5_D	Mercury	0.04	--	NT2_46	Y	2006	Oceanica 2007
T5_E	Mercury	0.05	--	NT2_46	Y	2006	Oceanica 2007
T7_A	Mercury	0.02	--	NT2_46	Y	2006	Oceanica 2007
T7_B	Mercury	0.03	--	NT2_46	Y	2006	Oceanica 2007
T7_C	Mercury	0.02	--	NT2_46	Y	2006	Oceanica 2007
T7_D	Mercury	0.05	--	NT2_46	Y	2006	Oceanica 2007
T7_E	Mercury	0.03	--	NT2_46	Y	2006	Oceanica 2007
T1_40A	Selenium	6.6	wet	NT2_46	Y	2011	Oceanica 2012
T1_40B	Selenium	7	wet	NT2_46	Y	2011	Oceanica 2012
T1_40C	Selenium	8.4	wet	NT2_46	Y	2011	Oceanica 2012
T1_40D	Selenium	3.4	wet	NT2_46	Y	2011	Oceanica 2012
T1_40E	Selenium	8	wet	NT2_46	Y	2011	Oceanica 2012
T5_40A	Selenium	6.9	wet	NT2_46	Y	2011	Oceanica 2012
T5_40B	Selenium	3.1	wet	NT2_46	Y	2011	Oceanica 2012
T5_40C	Selenium	4.1	wet	NT2_46	Y	2011	Oceanica 2012
T5_40D	Selenium	2.1	wet	NT2_46	Y	2011	Oceanica 2012
T5_40E	Selenium	4.3	wet	NT2_46	Y	2011	Oceanica 2012
T7_40A	Selenium	4.9	wet	NT2_46	Y	2011	Oceanica 2012
T7_40B	Selenium	2.5	wet	NT2_46	Y	2011	Oceanica 2012
T7_40C	Selenium	3.6	wet	NT2_46	Y	2011	Oceanica 2012
T7_40D	Selenium	6.5	wet	NT2_46	Y	2011	Oceanica 2012
T7_40E	Selenium	3.9	wet	NT2_46	Y	2011	Oceanica 2012
T1_A	Selenium	2.5	--	NT2_46	Y	2006	Oceanica 2007
T1_B	Selenium	1.7	--	NT2_46	Y	2006	Oceanica 2007
T1_C	Selenium	1.7	--	NT2_46	Y	2006	Oceanica 2007
T1_D	Selenium	1.5	--	NT2_46	Y	2006	Oceanica 2007
T1_E	Selenium	2.5	--	NT2_46	Y	2006	Oceanica 2007
T5_A	Selenium	2.5	--	NT2_46	Y	2006	Oceanica 2007
T5_B	Selenium	1.7	--	NT2_46	Y	2006	Oceanica 2007
T5_C	Selenium	1.6	--	NT2_46	Y	2006	Oceanica 2007
T5_D	Selenium	1.9	--	NT2_46	Y	2006	Oceanica 2007
T5_E	Selenium	2.4	--	NT2_46	Y	2006	Oceanica 2007
T7_A	Selenium	2	--	NT2_46	Y	2006	Oceanica 2007
T7_B	Selenium	1.5	--	NT2_46	Y	2006	Oceanica 2007
T7_C	Selenium	1.6	--	NT2_46	Y	2006	Oceanica 2007
T7_D	Selenium	2.5	--	NT2_46	Y	2006	Oceanica 2007
T7_E	Selenium	1.2	--	NT2_46	Y	2006	Oceanica 2007

Notes:

mg/kg = milligrams per kilogram

Table D2

Summary Statistics for Bioacumulative Metals in Sea Stars at Each Transect

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Analyte	Transect	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Mean Concentration (mg/kg)	Standard Deviation
Cadmium	T1	0.04	0.14	0.09	0.03
Cadmium	T5	0.04	0.25	0.11	0.07
Cadmium	T7	0.07	0.18	0.113	0.04
Mercury	T1	0.04	0.11	0.067	0.03
Mercury	T5	0.02	0.11	0.066	0.03
Mercury	T7	0.02	0.15	0.061	0.04
Selenium	T1	1.5	8.4	4.33	2.82
Selenium	T5	1.6	6.9	3.06	1.65
Selenium	T7	1.2	6.5	3.02	1.7

Notes:

mg/kg = milligrams per kilogram

Table D3

Analysis of Variance Results for Bioaccumulative Metals Across Transects

EQG Identification and Derivation for Low Reliability Values of Select Metals in Cockburn Sound

Alcoa Kwinana Refinery - Kwinana, Western Australia

Analyte	Degrees of Freedom	Sum of Squares	Mean of Squares	F-value	P-value
Cadmium	2	0.06	0.03	0.62	0.55
Mercury	2	0.05	0.02	0.39	0.68
Selenium	2	0.09	0.05	0.72	0.5

Figures

Figures

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Location of biota tissue sampling sites for the 2006 and 2011 nearshore survey

0 600 1,200 2,400 3,600 4,800 m

1 cm = 400 m [Page Size: A3]

Alcoa of Australia

EHS Support

Perth

Figure D1

CREATED BY:	D. Barnes
APPROVED BY:	E. Bloom
PROJECT REF. NO:	PTY.06491
MAP PROJECTION:	Transverse Mercator
GRID/DATUM:	GDA2020 MGA Zone 50
SCALE:	1:40,000
AERIAL IMAGE SOURCE:	ESRI Basemap Nearmap Pty Ltd

N

Attachment E Selenium Dietary Exposure Model for Cockburn Sound

MEMO

To: [redacted]

From:

Cc:

Date: 30 July 2025

[redacted]

Subject: Selenium Dietary Exposure Model for Cockburn Sound

Introduction

This memorandum was prepared by EHS Support Pty Ltd ("EHS Support") on behalf of Alcoa of Australia ("Alcoa") to describe a lines-of-evidence assessment to understand the bioaccumulation of aqueous selenium in Cockburn Sound, which is adjacent to the Alcoa Kwinana Refinery located on Hogg Road, Naval Base, Western Australia 6165 (Lot 102 on Parcel 18242, "Refinery" or "Site"). This document was developed in response to the comment letter received from the Auditor's Supporting Expert Team (SET) on 21 January 2025 regarding the *Relevant and Applicable Environmental Quality Guidelines (EQGs) for Cockburn Sound - EQG Identification and Derivation for Low Reliability Values of Select Metals* ("Derivation Memo") prepared by EHS Support dated March 26, 2024. The Derivation Memo specifically sought to incorporate contemporised marine toxicity data and the most current guidelines (Warne et al., 2018) to derive EQGs that would replace low reliability values for select metals, including selenium.

In the comment letter, the SET acknowledged that the EQG for selenium was derived in accordance with the species sensitivity distribution (SSD) methodology described in Warne et al., (2018), but recommended supplemental works to directly assess the bioaccumulation pathway. The approach enacted to assign levels of species protection for bioaccumulative constituents within the Australia and New Zealand Guidelines (ANZG) is considered an indirect, surrogate assessment of bioaccumulative toxicity. For example, if the level of species protection for a given waterway is 95 percent, it would be increased to 99 percent for bioaccumulative constituents (ANZG, 2018), to indirectly account for bioaccumulative toxicity whilst maintaining a species protection level consistent with the beneficial uses of the waterway.

A lines-of-evidence assessment was conducted to directly consider the bioaccumulation pathway and justify adopting the SSD as-is and to maintain the 95th percent species protection level for selenium. The overarching objective of this memo is to qualitatively and quantitatively assess the bioaccumulation of selenium in Cockburn Sound. This will be accomplished through:

- Review of the fate and transport of selenium in the marine environment to understand biotic and abiotic processes affecting exposure conditions.
- Summarizing key habitats in Cockburn Sound to inform receptor selection and model parameterization (this will ultimately support the development of a conceptual exposure model);
- Evaluation of existing marine tissue data collected adjacent to the Site to assess whether conditions differ significantly from background tissue concentrations; and,
- Conducting desktop-based dietary modeling of aqueous selenium to assess concentrations at which potential adverse effects could be occurring.

Selenium in the Marine Environment

An understanding of selenium chemical speciation, mobility, and transport processes in the marine environment is needed to characterise ecological exposure conditions to marine fauna. The following provides a brief overview of the behavior of selenium in marine waters.

Selenium Distribution

Selenium (Se) distribution in the natural environment is ubiquitous, and its cycle spans all components of the of Earth's systems (i.e., atmosphere, lithosphere, hydrosphere, and biosphere). Se is a nonmetallic element in the sulfur group of the periodic table and shares similar fundamental characteristics with sulfur. Se is an essential micronutrient for the growth and proliferation of biomass, but it can also function as a toxicant if it is present in excessive amounts. The ocean represents the largest global sink for primary emissions of Se, and atmospheric deposition is the main source of the element to the ocean (Mason et al., 2018). Additional sources include groundwater, surface water, dust deposition, and volcanic or industrial emissions (Winkel et al., 2015).

Within marine coastal waters, Se cycling is incredibly complex. Se exists in multiple oxidation states, including Se(VI), Se(IV), Se(0), and Se(-II) (Breuninger et al., 2023). Variability in oxidation states allows Se to interact with a wide range of chemical species, forming a variety of dissolved and particulate compounds. In oxygenated surface waters, the dominant dissolved Se species are the oxyanions selenate (SeO_4^{2-}, or Se(VI)) and selenite (SeO_3^{2-}or $HSeO_3^-$, or Se(IV)), and organic selenides (Se(-II)) present as fine particulate organic matter (USEPA, 2021, and references therein). The relative abundance of dissolved Se(VI), Se(IV), and Se(-II) species in marine systems varies with depth (Cutter & Bruland, 1984), and the vertical distribution of Se follows that of key nutrients (e.g., phosphorus). In surface waters, organic Se(-II) predominates, while Se(VI) and Se(IV) concentrations generally increase with depth (Mason et al., 2018). Elemental Se(0) is the least abundant species and exists primarily in reduced sediments. Redox and photooxidation reactions can cause transformations between these Se species, but the reaction rates are often negligible.

Selenium Bioavailability

Selenium bioavailability is complex, dependent on chemical speciation, and varies for dissolved and particulate forms of the micronutrient. In general, Se bioavailability is greatest for dissolved rather than particulate species. Dissolved Se bioavailability is greatest in the order of Se(IV) and organic Se(-II) species, followed by Se(VI) (Mason et al., 2018; USEPA, 2021, and references therein). Dissolved Se species in the water column are readily assimilated by primary producers (e.g., phytoplankton, periphyton) and incorporated into biomass as organic Se. This step represents the greatest magnitude transfer of Se accumulation from abiotic to biotic pools within the system (USEPA, 2021, and references therein). These primary producers, along with organic Se(-II) in detritus, and Se(0), Se(IV), and Se(VI) bound to sediment particles, comprise the particulate Se fraction (USEPA, 2021). Since dissolved Se in the water column is primarily depleted by basal trophic level organisms, its bioavailability to higher trophic levels principally occurs through the ingestion of, and exposure to, particulate Se.

The primary mechanism of Se toxicity in aquatic systems operates through bioaccumulative pathways and trophic transfer. Bioaccumulation occurs as predators consume lower trophic level organisms that have assimilated bioavailable forms of Se into their tissues, leading to an increase in Se tissue concentrations in the consumer. Since bioavailable dissolved Se species are readily assimilated by primary producers, the potential for Se toxicity in a system is principally dependent upon concentrations found at basal trophic levels and in particulates (e.g., algae, phytoplankton, detritus, and sediment) and is indirectly related to dissolved concentrations in the water column. Consequently, Se toxicity depends on site-specific factors, such as Se partitioning, food web structure, and hydrology (USEPA, 2021). There is evidence of reduced Se toxicity in marine water relative to freshwater systems due to higher sulfate concentrations. Sulfate and Se compete for uptake in microorganisms owing to the similarity between the sulfate and selenate ions (Williams et al., 1994; Ogle & Knight, 1996). This antagonistic interaction decreases Se(VI) bioavailability and uptake and could indirectly reduce bioaccumulative toxicity. Furthermore, several studies suggest that Se(VI) is not assimilated into marine phytoplankton, especially in the presence of sulfate (Mason et al., 2018, and references therein; Fournier et al., 2010). These site-specific factors that impact Se bioavailability, in turn, influence Se bioaccumulation.

Selenium Bioaccumulation

Se bioaccumulation and associated toxicity can be influenced by several system-specific factors present in Cockburn Sound. Water chemistry parameters can influence inorganic Se uptake rates, but the median pH of 8.2 s.u. in the available background data (EHS Support, 2024) suggests that the slightly alkaline environment is conducive to inorganic Se (i.e., Se(IV) and Se(VI)) bioavailability and uptake (Sharma et al., 2015). Hydrodynamics also influence Se mobility and speciation (and therefore bioavailability) so the dynamic, intertidal environment present in Cockburn Sound will impact site-specific Se toxicity. Tidal movements provide inherent spatial and temporal heterogeneity related to water residence time, which will influence the presence of Se in the water column, its speciation, and its bioavailability (USEPA, 2021). In general, shorter water residence time is associated with decreased Se bioaccumulation. The relationship between bioaccumulation and residence time reflects the complex interaction between site-specific factors such as the organic content, redox potential, and food web specifics (USEPA, 2021, and references therein).

Se enters the aquatic food web through primary producers (e.g., plants, algae, microbes), which assimilate the micronutrient from sediments and dissolved forms in the water column. As trophic level increases, Se bioaccumulation and transfer propagates through ingestion (i.e., the long-term predation of lower trophic level species with relatively high Se tissue concentrations). Bioaccumulation can also occur through direct contact with Se in sediments, detritus, or dissolved forms in the water column, but this occurs to a lesser extent (USEPA, 2021). As noted above, the bioavailability and toxicity of Se is influenced by its chemical form and its partitioning between sediments and the water column. In shallow coastal habitats where sediment-water interactions are more pronounced, dissolved Se species are typically depleted through assimilation, sorption, and volatilization reactions (Breuninger et al., 2023). Se toxicity is likely greater in these areas due to the relative abundance of organic Se species in primary producers and particulates (algae, detritus, and sediment), increasing bioaccumulation rates. In deeper waters, where primary productivity is less significant, bioavailability of Se is generally higher and dissolved inorganic forms (e.g., Se(IV), Se(VI)) predominate (Mason et al., 2018; Breuninger et al., 2023). Therefore, when evaluating site-specific Se cycling and potential exposure to receptors, it is critical to consider the different habitat types that are present.

Key Habitats in Cockburn Sound

Given the complexity of Se transport in marine ecosystems, identification of key habitats in Cockburn Sound is needed to inform receptor selection and subsequent model parameterization. A detailed understanding of ecosystem receptors and their trophic interactions is foundational to the assessment of Se trophic transfer through the dietary pathway.

There are three primary habitats within Cockburn Sound—shallow intertidal zones, seagrass meadows, and deep water. Each habitat type supports distinct assemblages of species that occupy different life stages and exhibit unique foraging behaviors. The ecological niche of an individual determines its potential for Se exposure and uptake, thereby influencing the risk of bioaccumulation at higher trophic levels.

Shallow Intertidal Zone

The shallow intertidal habitat, found along the eastern side of Cockburn Sound, is characterized by high hydrodynamic activity and a sandy, predominantly unvegetated benthic substrate. This habitat supports a diverse array of species, including benthic organisms, spawning fish, crustaceans, and top predators, all of which are exposed to both sediment-bound and dissolved forms of Se. The shallow intertidal zone is proximal to anthropogenic sources at the Site, making it the critical focus for assessing risk of exposure.

Seagrass Meadows

Seagrass meadows, located along the western side of Cockburn Sound, provide important nursery areas for species during juvenile and early adult stages. These meadows are highly productive and serve as a key source of aquatic vegetation, algae, and detritus, which are essential dietary components for species inhabiting the area. Species in these meadows are exposed to both sediment-bound and dissolved forms of Se.

Deep Water

The deep-water habitat represents the deepest waters of Cockburn Sound and is primarily utilized by adult fish and mobile predators. Species in this habitat are typically less exposed to sediment bound Se but may accumulate Se through dietary intake, particularly through trophic transfer from species originating from more contaminated shallow areas.

This review of the three primary habitat types in Cockburn Sound suggests that the shallow intertidal zone should be the focal point for an assessment of potential Se exposure risk to receptors. This habitat zone supports a variety of species at several life stages and facilitates food web complexity at several trophic levels. From a biogeochemical perspective, Se bioaccumulation and associated toxicity are likely to be greater in shallow coastal areas than deeper waters (Breuninger et al., 2023; Mason et al., 2018). Furthermore, the proximity of the shallow intertidal zones to the Site incurs the greatest potential for exposure to increased Se concentrations. To further the evaluation of Se exposure risk in the shallow intertidal zone, receptors of interest were identified at multiple trophic levels.

Receptors of Interest

Receptors of interest that may utilize the shallow intertidal zone are summarized in **Table 1.** Food web interactions between ecological receptors are summarized in **Figure 1.** The following factors were considered for the selection of proposed ecological receptors:

- **Exposure potential to sediment-associated contaminants:** Species exposed to sediments through direct or incidental ingestion, contact, or consumption of sediment-exposed prey are more likely to accumulate Site-related toxicants. Species with smaller home ranges or those restricted to the site, such as juvenile fish or benthic organisms, face greater exposure compared to migratory species or those with larger ranges.
- **Bioaccumulation and biomagnification potential:** Species at higher trophic levels, particularly piscivores, have a greater capacity for bioaccumulating and biomagnifying contaminants due to their position in the food web.
- **Societal and cultural importance:** Special consideration is given to species that have conservation status, as well as those with significant commercial or recreational value to local communities.
- **Ecological role:** Species with specialized foraging habits or that serve a unique ecological function, such as those that feed on benthic organisms in shallow intertidal zones, are prioritized in receptor selection.
- **Sensitivity to contaminants:** Species known to be particularly sensitive to specific contaminants, such as the Pied Cormorant and Little Penguin, are given priority in the receptor selection process.

TABLE 1 COCKBURN SOUND RECEPTORS OF INTEREST

Receptor Group	Common Name	Scientific Name	Habitat
Avian Fauna			
Piscivore*	Pied Cormorant	*Phalacrocorax varius*	Seagrass meadow, shallow intertidal
Piscivore/Invertivore	Little Penguin	*Eudyptula minor*	Seagrass meadow, shallow intertidal
Piscivore*	Pelican	*Pelecanus conspicillatus*	Deep water, shallow intertidal
Piscivore/Invertivore	Common Tern	*Sterna Hirundo*	Seagrass meadow, shallow intertidal
Fish			
Piscivore/Invertivore	Scaly Mackerel	*Scomber australasicus*	Deep water, seagrass meadow, shallow intertidal,
Planktivore	Sprat	*Sprattus spp.*	Seagrass meadow, shallow intertidal
Piscivore/Invertivore	Pink Snapper (Juvenile)	*Chrysophrys auratus*	Seagrass meadow, shallow intertidal
Piscivore/Invertivore	Pink Snapper (Adult)	*Chrysophrys auratus*	Deep water, shallow intertidal (spawning)
Marine Mammals			
Piscivore (Top Predator)	Bottlenose Dolphin	*Tursiops spp.*	Deep water, shallow intertidal
Piscivore/Avivore	Australian Sea Lion	*Neophoca cinerea*	Seagrass meadow, shallow intertidal

Receptor Group	Common Name	Scientific Name	Habitat
Crustaceans			
Benthic Omnivore/Invertivore	Blue Swimmer Crab	*Portunus armatus*	Deep water, seagrass meadow, shallow intertidal
Echinoderms			
Benthic Carnivore/Invertivore	Sea Star	*Archaster angulatus, Patiriella spp., or Astropecten spp.*	Deep water, shallow intertidal
Aquatic Vegetation			
Primary Producer	Seagrass	*Zostera spp.*	Seagrass meadow

Notes:
* = Top predator

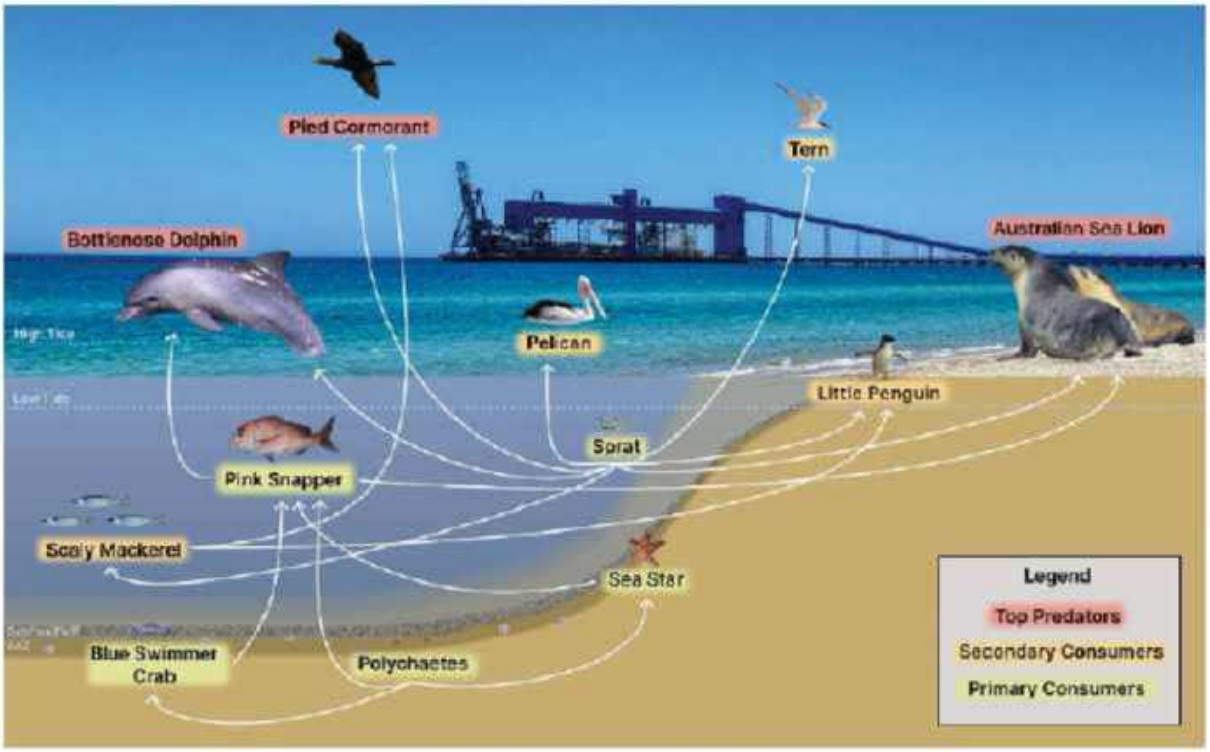

FIGURE 1 – FOOD WEB INTERACTIONS BETWEEN ECOLOGICAL RECEPTORS

The habitat and receptor selection processes revealed key trophic relationships and highlighted the importance of certain candidate species for the dietary model evaluation of Se bioaccumulation in Cockburn Sound. The pink snapper (*Chrysophrys auratus*) was selected as the candidate species for the model due to its conservation status and its ecological niche as the predator of several key invertebrate prey species (*A. angulatus, Portunus armatus, Polychaeta spp.*) in the shallow intertidal zone.

Lines-of-Evidence Assessment

A detailed lines-of-evidence assessment was conducted to evaluate whether derived Se guidelines are protective of receptors in Cockburn Sound. This assessment included a qualitative evaluation of existing marine tissue data collected adjacent to the Site, and a desktop-based dietary modeling of aqueous Se to assess concentrations at which potential adverse effects to receptors could be occurring.

Existing Site-Specific Tissue Data Review

To assess the influence of Se on higher-order wildlife in Cockburn Sound, an analysis of available sea star (*A. angulatus*) tissue data was performed. *A. angulatus* were identified as a receptor of interest, as they inhabit the sediments of shallow intertidal zones, feeding primarily on detritus and microorganisms. Their ecological niche presents a key opportunity to evaluate Se bioaccumulation adjacent to the Site. **Figure 2** illustrates the distribution of tissue concentrations in *A. angulatus* collected in 2006 and 2011 at two transects adjacent to the Site (T1 and T5) and in a background transect 11 kilometers (km) north of the Site (T7). Each transect includes whole body wet weight tissue concentrations associated with five *A. angulatus* replicates. Arithmetic mean tissue Se concentrations (mg/kg dw) are depicted with diamonds and standard deviations are shown with dashed lines.

A one-way analysis of variance (ANOVA) test was performed to assess whether transect was influencing log10-transformed Se tissue concentrations. This test found that transect location did not have a significant effect on tissue concentration ($p = 0.49$). Therefore, there is no statistically significant difference in *A. angulatus* tissue concentrations between the background (11 km north) and the two adjacent transects to the Site. This qualitative assessment provides important information about potential risks to higher-order wildlife and suggests there is no increased risk of Se exposure with proximity to the Site. An additional quantitative evaluation of dietary pathways is provided below to account for site-specific food web dynamics and to substantiate these conclusions.

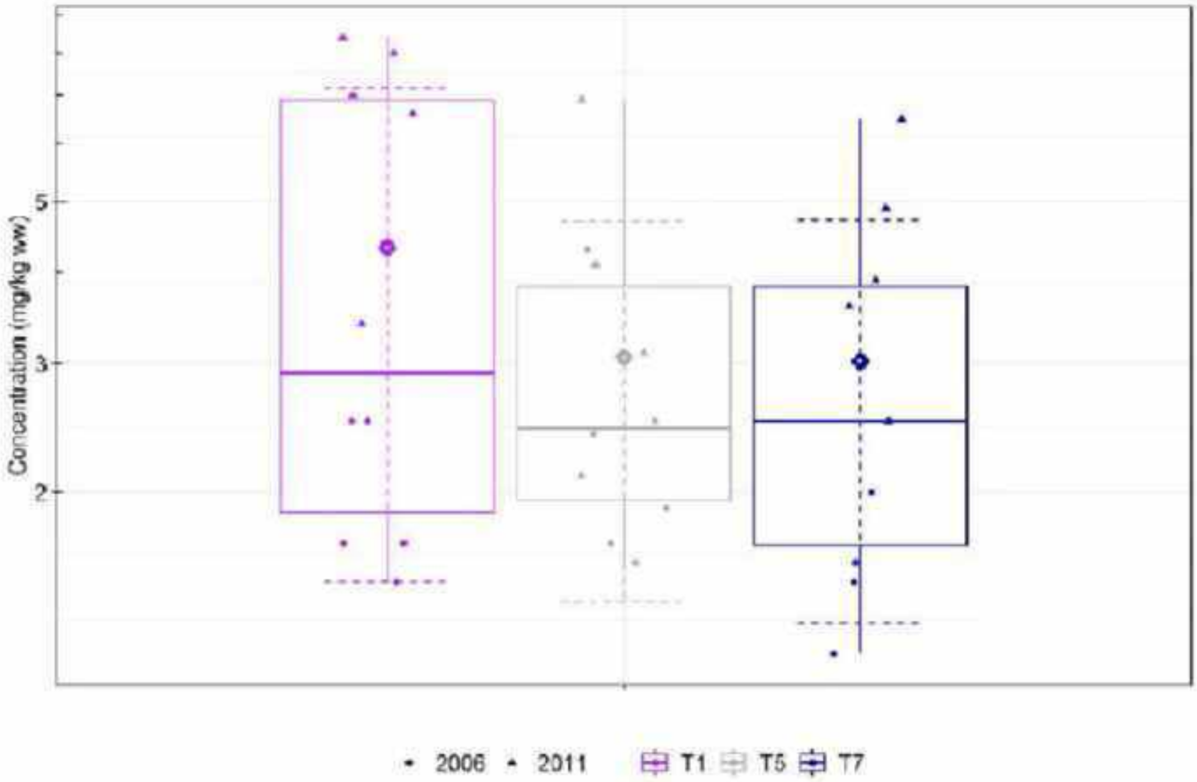

FIGURE 2 – SEA STAR (*A. ANGULATUS*) WHOLE BODY TISSUE SELENIUM CONCENTRATIONS BY TRANSECT

Quantitative Dietary Modeling Assessment

The purpose of a dietary model is to quantify the potential for adverse bioaccumulative effects of Se to Cockburn Sound receptor species. Here, we refer to the framework of Presser and Luoma (2010) to establish an ecosystem-scale model that conceptualizes and parameterizes the relevant variables that dictate Se bioaccumulation. The model presented here utilizes biogeochemical and physiological data from site-specific sources (where available) to establish an EQG for Se that offers adequate protection to key receptors. To address key data gaps, peer-reviewed literature sources were identified and included in the assessment. Principal model parameters are discussed below along with any key assumptions and their associated uncertainties.

Model Parameterization

The model framework of Presser and Luoma (2010) identifies protective water column Se concentration values based on available toxicity guidelines. These guidelines are often based on toxicity to oviparous vertebrate (i.e., fish and bird) species, as they are the most sensitive groups to Se effects (USEPA, 2021). In the absence of available marine or ANZG Se tissue criteria, this model is based on fish tissue concentration (C_{fish}) thresholds promulgated by the USEPA and Environment and Climate Change Canada (ECCC) for freshwater ecosystems. A summary of these criteria is presented in **Table 2.**

Table 2 Available Fish Tissue Se Toxicity Guidelines

C_{fish} (mg/kg dw)	Tissue Type	Source
15.1	Egg-ovary	USEPA, 2021
8.5	Whole-body	
11.3	Muscle	
14.7	Egg-ovary	ECCC, 2022
6.7	Whole-body	

To quantify bioaccumulation of Se to the candidate fish species, we determined a trophic transfer factor (TTF_{fish}). TTFs are species specific measurements that quantify the amount of Se that transfers from one trophic level to another in the food web and are based upon kinetic measurements of ingestion rate (IR), assimilation efficiency (AE), and efflux rate (K_e). Since laboratory studies that quantify these kinetics in fish species are sparse, Presser and Luoma (2010) recommend a simplified equation that relates fish tissue Se concentrations to that of the prey, using:

$$TTF_{fish} = C_{fish} \div C_{invertebrate},$$

where C_{fish} is the concentration of Se in the muscle or whole-body tissue, and $C_{invertebrate}$ is the concentration of Se in the prey species. This calculation requires both concentrations reported on a dry-weight (dw) basis. For *C. auratus*, a site-specific TTF_{fish} could not be calculated due to a lack of applicable prey tissue Se concentrations on a dw basis. While the *A. angulatus* dataset detailed in **Figure 2** provides site-specific tissue data, all concentrations are reported on a wet-weight (ww) basis with no data available for conversion. Therefore, the default TTF_{fish} value of 1.1 was adopted in the model per the guidance of Presser and Luoma (2010). While the lack of a species-specific TTF represents an uncertainty, Presser and Luoma (2010) state that the TTFs for all fish species reliably fall within a very narrow range (0.5 to 1.6).

The potential for Se toxicity in a system is principally dependent upon the base of the food web and the assimilation of dissolved and particulate Se into the tissues of lower trophic level organisms. It is therefore critical to identify TTFs for the prey species that higher trophic level organisms ingest. Key receptors in Cockburn Sound that are prey for fishes include *A. angulatus*, *P. armatus*, and *Polychaeta spp* (**Figure 1**). $TTF_{invertebrate}$ is calculated using the equation:

$$TTF_{invertebrate} = C_{invertebrate} \div C_{particulate},$$

where $C_{particulate}$ is the concentration of Se in particulate matter. Species-specific TTFs were not calculated due to a lack of available prey tissue Se concentrations on a dw basis. Presser and Luoma (2010) present broad categories of TTFs for invertebrates based on taxonomic groupings, including means < 1 for amphipods, 1.3 to 1.9 for crustaceans, 2.8 for aquatic insects, and >= 2.8 to 6 for clams and mussels. Since crustaceans like *P. armatus* typically comprise much of the diet for *C. auratus* in Cockburn Sound (Parsons et al., 2014; Usmar, 2012), they were selected as the key prey species in this dietary model. The arithmetic mean value of 1.6 calculated for the crustacean taxonomic group (Presser and Luoma, 2010), was therefore adopted as the representative $TTF_{invertebrate}$ value. While the lack of species-specific values represents an uncertainty, $TTF_{invertebrate}$ values show very little variation within taxonomic groups (Presser and Luoma, 2010).

The site-specific partitioning factor (K_d) between dissolved and particulate forms of Se is critical to understand due to the role of particulate Se in the bioaccumulative pathway. The transformation of dissolved Se to particulate forms (sediment, detritus, algae) is the basis for all subsequent trophic propagation of toxicity. K_d is calculated using the equation:

$$K_d = C_{particulate} \div C_{water-column},$$

where $C_{particulate}$ is the concentration (mg/kg dw) of Se in particulate matter and $C_{water-column}$ is the concentration (mg/L) of Se in the water column. K_d varies by orders of magnitude based on physicochemical characteristics of the water body and is a substantial source of uncertainty in the absence of thoroughly developed site-specific models (Presser and Luoma, 2010). In general, rivers and lakes tend to possess K_d values between 100 and 2,000, while estuaries and oceans possess K_d values greater than 5,000 (Presser and Luoma, 2010). To constrain the uncertainty associated with K_d selection, we parameterized three plausible values.

Scenario 1: Site-specific K_d

Background data compiled in the Derivation Memo (EHS Support, 2024) were used to determine $C_{water-column}$ based on the arithmetic mean of dissolved Se. In the absence of available $C_{particulate}$ data from the same dataset, available background sediment data was analysed from the *Oceanica 2012 Alcoa Nearshore Survey 2011 Data Report* (Oceanica, 2012). This report includes data from offshore sampling conducted in 2011. In total, ten cores (five nearshore, five offshore) were collected from seven transects and analysed for total extractable Se. Transects included both Site-adjacent and background locations within Cockburn Sound. To calculate $C_{particulate}$, we assumed the sediments would be routinely resuspended in the water column of Cockburn Sound during tidal mixing and could therefore serve as the particulate Se fraction. To maintain consistency with the Derivation Memo (EHS Support, 2024), all non-detect values were set to ½ of the laboratory reported quantitation limit. A summary of the $C_{water-column}$ and $C_{particulate}$ datasets, and the calculated site-specific K_d is presented in Table 3.

TABLE 3 SITE-SPECIFIC PARTITIONING COEFFICIENT (K_D) CALCULATION

Matrix	Analyte	Samples			Mean Concentration	Units	K_d
		Detected	Non-detected	Total			
Surface Water	Dissolved Se	5	54	59	0.00423	mg/L	11.82
Sediment	Total Extractable Se	0	70	70	0.05	mg/kg	

Scenario 2: Default K_d

In the absence of site-specific observations of particulate and dissolved Se, Presser and Luoma (2010) suggest the adoption of a default K_d of 1,000. However, the authors acknowledge that this may not be a conservative choice for estuaries or marine environments, as it is outside their typical range of K_d values (>5,000) (Presser and Luoma, 2010).

Scenario 3: Average marine K_d

Presser and Luoma (2010) calculated and compiled K_d values from various field studies using available $C_{water-column}$ and $C_{particulate}$ Se data. A summary of potentially comparable estuarine or marine sites is presented in Table 4. The arithmetic mean K_d of 13,594 from these sites was adopted as a plausible value.

TABLE 4 COMPILED ESTUARINE AND MARINE PARTITIONING COEFFICIENTS (K_d) FROM PRESSER AND LUOMA (2010)

K_d	Habitat	Literature Source
6,500	Great Marsh, DE	Velinsky and Cutter, 1991
7,817	San Francisco Bay, CA (1998-1999)	Cutter and Cutter, 2004; Doblin et al., 2006
9,456	Salton Sea estuary, Alamo River	LeBlanc and Schroeder, 2008
11,956	Salton Sea estuary, Whitewater River	LeBlanc and Schroeder, 2008
13,788	Outer San Francisco Bay, CA (1998-1999)	Cutter and Cutter, 2004; Doblin et al., 2006
15,000	Xiamen Bay, Fujian Province, China	Liu et al., 1987
17,391	Salton Sea estuary, New River	LeBlanc and Schroeder, 2008
21,500	San Francisco Bay, CA (1986; 1995-1996)	Presser and Luoma, 2006
18,942	Lower Newport Bay, CA	Presser and Luoma, 2009

Water Quality Guideline Calculation

The partitioning coefficient (K_d), trophic transfer factors for fish (TTF_{fish}) and invertebrates ($TTF_{invertebrate}$), and the applicable fish tissue guideline values (C_{fish}), determined above are used to calculate the water column concentration (C_{water}) for the protection of fish using the equation:

$$C_{water} = C_{fish} \div (TTF_{fish})(K_d)(TTF_{invertebrate}).$$

The key assumptions of this equation are 1) fish are consuming a single invertebrate diet, and 2) there is no area use factor applied. The dietary composition of fish species in Cockburn Sound is complex, with multiple prey species linked to the predators identified in the conceptual exposure model. Furthermore, since the model does not specify an area use factor, it is assumed that 100% of the diet of fishes and invertebrates is linked to the Site. Refinement of feeding areas would help determine the percentage of fish diet that can be linked to areas of concern. The framework presented by Presser and Luoma (2010) provides additional, more complex modeling equations to estimate C_{water}; however, the uncertainties required to parameterize the variables in the equation above would likely increase proportionally with model complexity.

The site-specific C_{water} Se concentrations for the protection of fish were evaluated using the identified USEPA and ECCC fish tissue guideline values (C_{fish}) and the three scenarios for K_d as detailed above. Results of this evaluation are presented in Table 5.

TABLE 5 CALCULATED WATER QUALITY GUIDELINES FOR COCKBURN SOUND

Scenario	C_{water} (ppb)	C_{fish} (ppm)	C_{fish} tissue type	TTF_{fish}	K_d	$TTF_{invertebrate}$
1 (*Site-specific*)	726	15.1	Egg-ovary	1.1	11.82	1.6
	409	8.5	Whole body			
	543	11.3	Muscle			
	707	14.7	Egg-ovary			
	322	6.7	Whole body			
2 (*Default*)	8.6	15.1	Egg-ovary	1.1	1,000	1.6
	4.8	8.5	Whole body			
	6.4	11.3	Muscle			
	8.4	14.7	Egg-ovary			
	3.8	6.7	Whole body			

Scenario	C_{water} (ppb)	C_{fish} (ppm)	C_{fish} tissue type	TTF_{fish}	K_d	$TTF_{invertebrate}$
3 (*Literature-based*)	0.63	15.1	Egg-ovary	1.1	13,594	1.6
	0.36	8.5	Whole body			
	0.47	11.3	Muscle			
	0.61	14.7	Egg-ovary			
	0.28	6.7	Whole body			

The order of magnitude variability in estimates of protective Se concentrations (C_{water}) from the three modeled scenarios can be attributed to differences in K_d, which is a known driver of uncertainty in this approach (Presser and Luoma, 2010). The calculated site-specific K_d in the first scenario should be the most plausible value to produce reliable estimates of C_{water}, but the results are an order of magnitude greater than those generated by the SSD in the Derivation Memo (EHS Support, 2024) and the revised SSD in **Enclosure A: Response to Comments Ledger**. The site-specific K_d is also multiple orders of magnitude lower than comparable estuarine and marine sites from the literature. Therefore, the assumptions required to generate the site-specific K_d value from available background data may not be sufficient to capture the true concentration of particulate Se in the system ($C_{particulate}$). However, it should be noted that no total extractable Se was detected in the evaluated sediment samples (**Table 3**), reducing potential risk to receptors through the primary exposure pathway. Furthermore, in the background dataset compiled for the Derivation Memo (EHS Support, 2024), there were no detections for total Se in the water column and few detections for dissolved Se (**Table 3**). Based on the available data, there is likely minimal risk of Se toxicity to receptors adjacent to the Site.

Further refinement of $C_{particulate}$ and K_d is recommended to reduce uncertainties in the output produced by this model. Regardless, it is likely that the site-specific K_d is lower than the estuarine and marine values compiled by Presser and Luoma (2010). The default K_d suggested by Presser and Luoma (2010) produced comparable outputs to the 99th percentile species protection level (9.3 µg/L) estimated by the SSD, yet values are still below the 95th percentile background Se concentration of 10 µg/L.

Conclusion

The lines of evidence assessment presenting site-specific invertebrate tissue data and desktop dietary modeling of the pink snapper (*C. auratus*) using a K_d calculated with site-specific data support the conclusions that:

1. Tissue concentrations observed in a key invertebrate receptor species (*A. angulatus*) adjacent to the Site do not differ significantly from those observed in background areas over 11 km away, and,
2. Surface water concentrations of selenium associated with adverse effects in waters adjacent to the Site range from 322 µg/L to 726 µg/L.

The dietary modeling framework utilised here includes conservative assumptions in determining a protective Se concentration in the water column. First, the model assumes that water column concentrations of Se are uniformly distributed and does not account for biogeochemical processes or mixing dynamics associated with tidal movements in Cockburn Sound. Inherent spatial and temporal heterogeneity in the system will influence Se exposure to receptors, particularly in the shallow intertidal habitat zone. Second, no specific area use factor is applied. Without a specified area use factor, it is assumed that receptors would spend 100% of their time in areas at the modeled surface water Se concentrations.

These findings demonstrate that both the 99th percent species protection level of 9.3 µg/L and the 95th percent species protection level of 31 µg/L generated through the SSD are protective to higher trophic levels and as a site-specific limit, respectively. However, there are acknowledged uncertainties associated with this lines-of-evidence assessment, specifically regarding parameterisation of the quantitative dietary model, that preclude the adoption of the 95th percent species protection level (31 µg/L) derived for Site monitoring efforts at this time.

Additional model refinement through the collection of site-specific parameters is recommended to reduce acknowledged uncertainties and develop a more reliable EQG that is protective of receptors in Cockburn Sound. Focused Site sampling efforts should capture instantaneous measurements of particulate and dissolved selenium fractions in the water column across different spatial and temporal (i.e., tidal) scales in Cockburn Sound. In addition, collection of interstitial porewater samples would also provide increased confidence in the equilibrium relationship between matrices in the active marine environment. The resulting, robust dataset will provide an understanding of the fractional distribution and concentration of selenium present adjacent to the Site and in background areas and will refine our understanding of mixing dynamics and geochemical processes within the intertidal and subtidal zones. Until refinement occurs, the 95th percentile background concentration of 10 µg/L will be adopted as the interim selenium EQG for the purpose of advancing the program. Further assessment may be required in the future to develop a more reliable EQG that is protective of receptors in Cockburn Sound.

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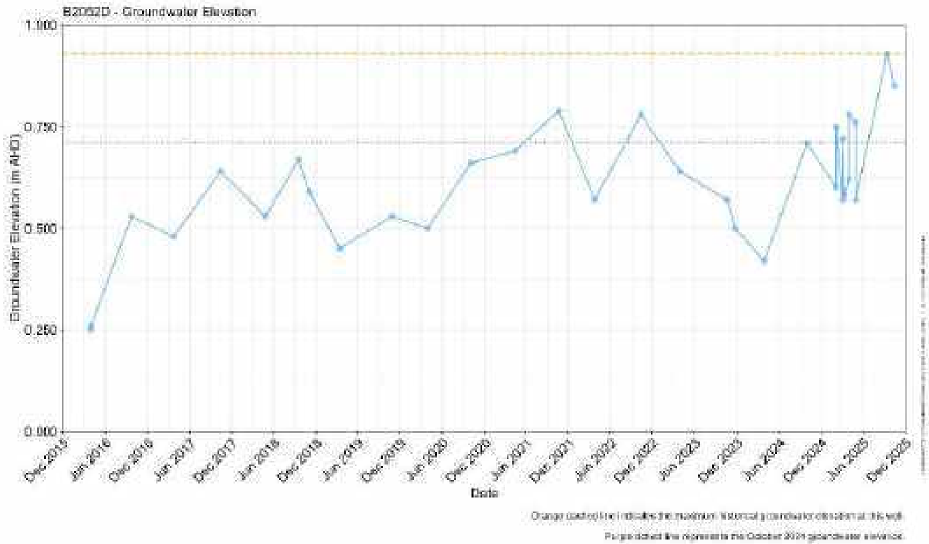
Appendix E Trigger Bores – Historical Groundwater Levels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0.250
0.000
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Jun 2016
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Dec 2017
Jun 2018
Dec 2018
Jun 2019
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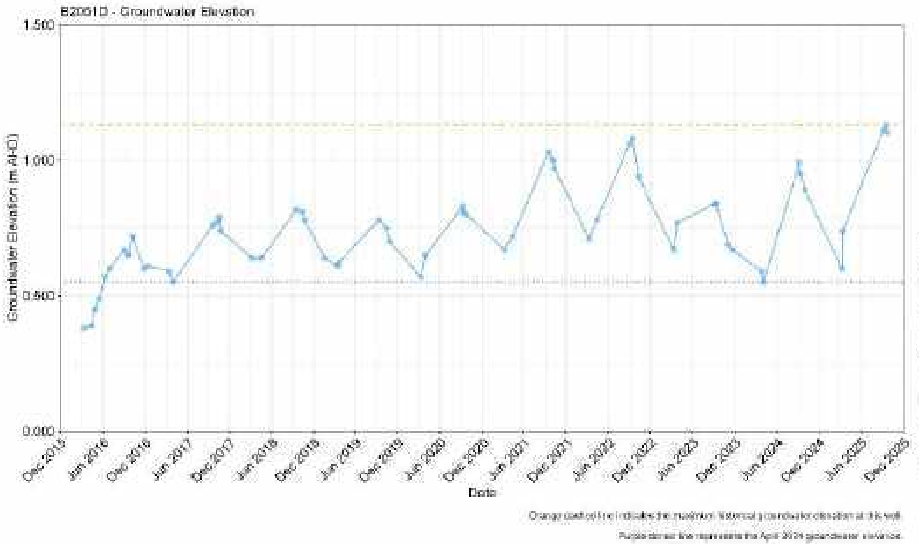
Jun 2025
Dec 2025
Date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Jun 2016
Dec 2016
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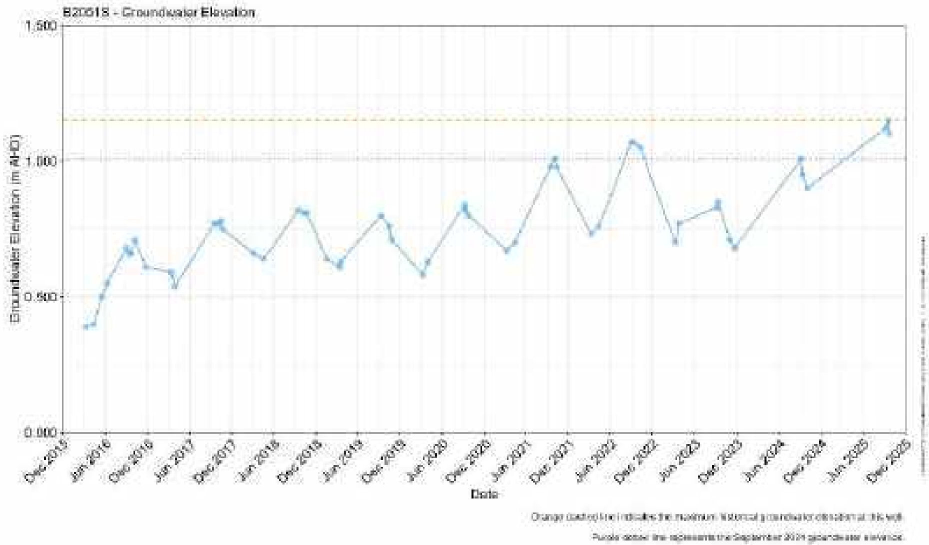
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0.500
0.000
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Jun 2016
Dec 2016
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Jun 2019
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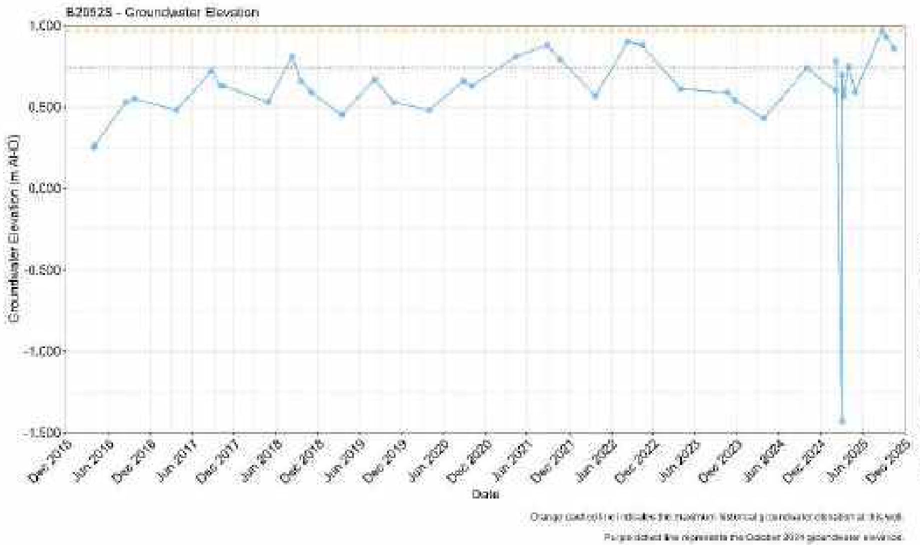
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-1.000
-1.500
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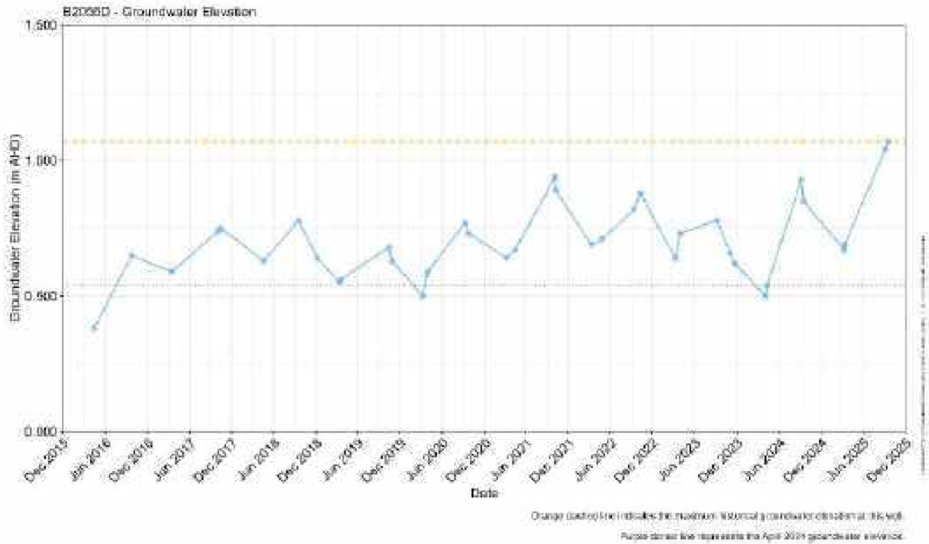
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Jun 2016
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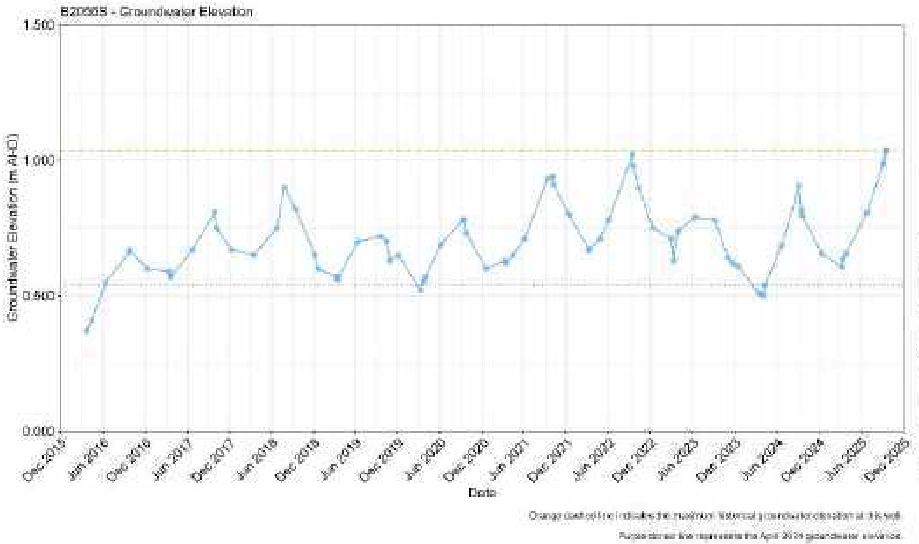
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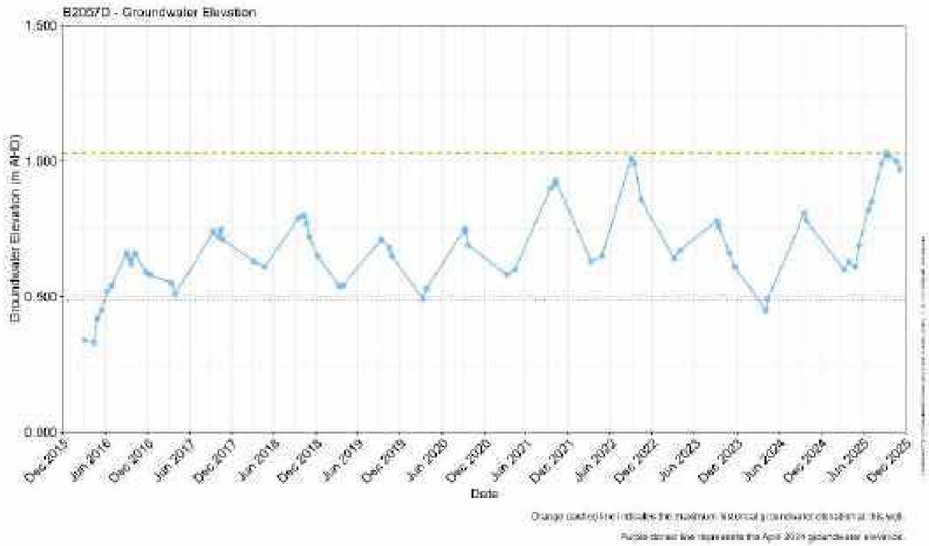
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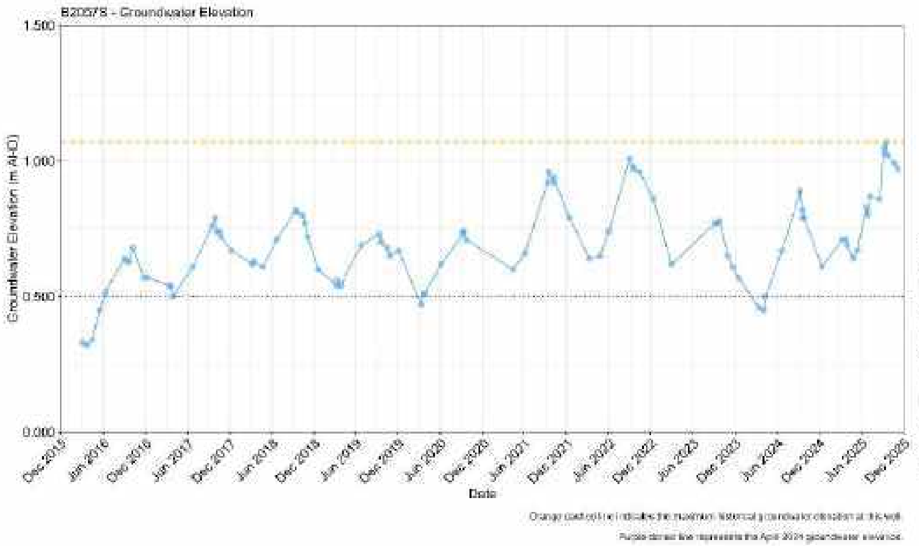
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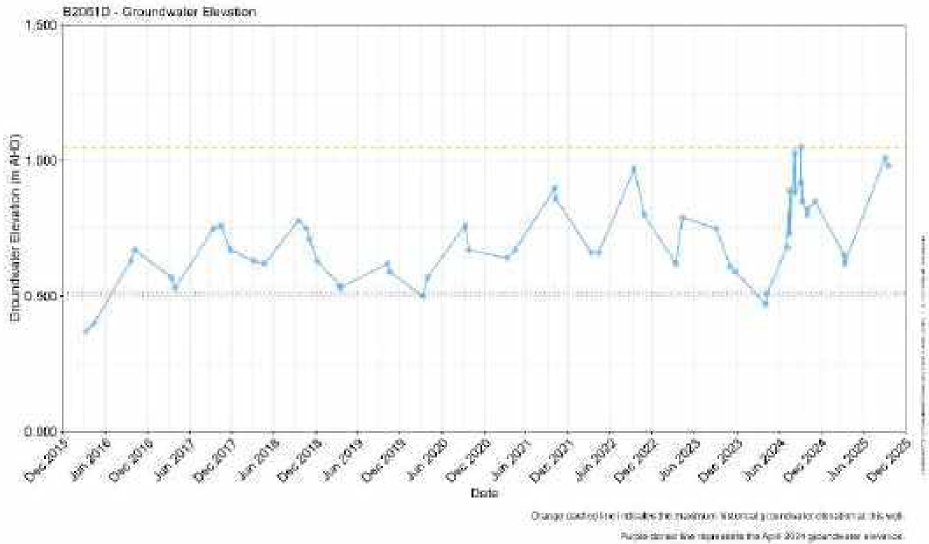
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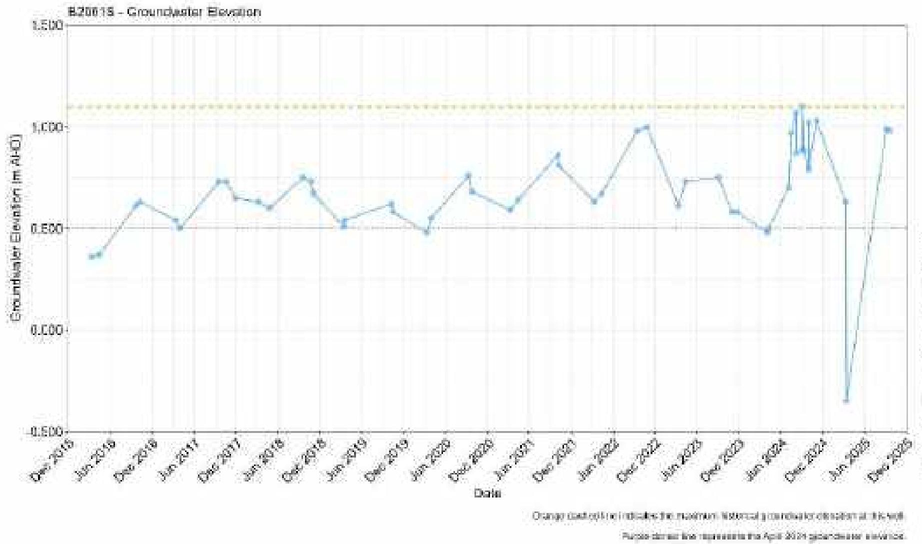
Purple dotted line represents the April 2024 groundwater elevation.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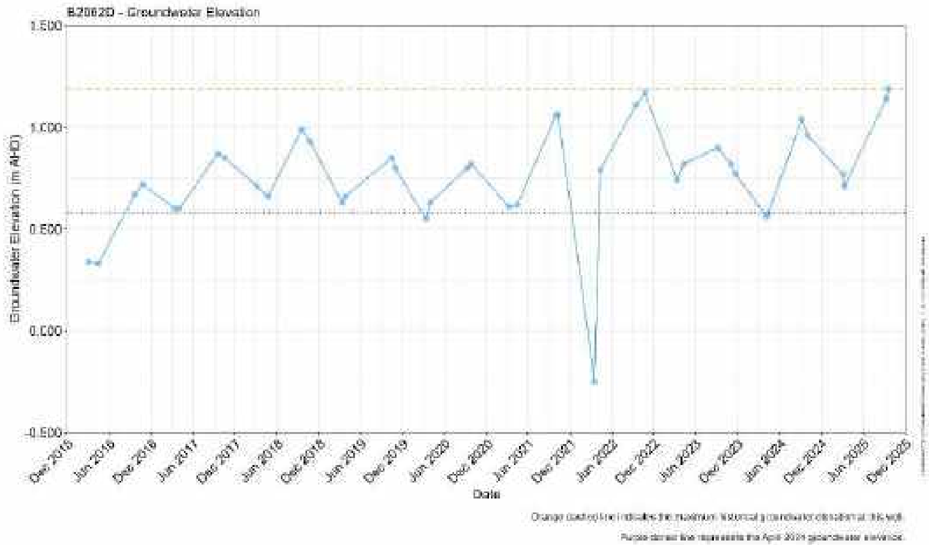
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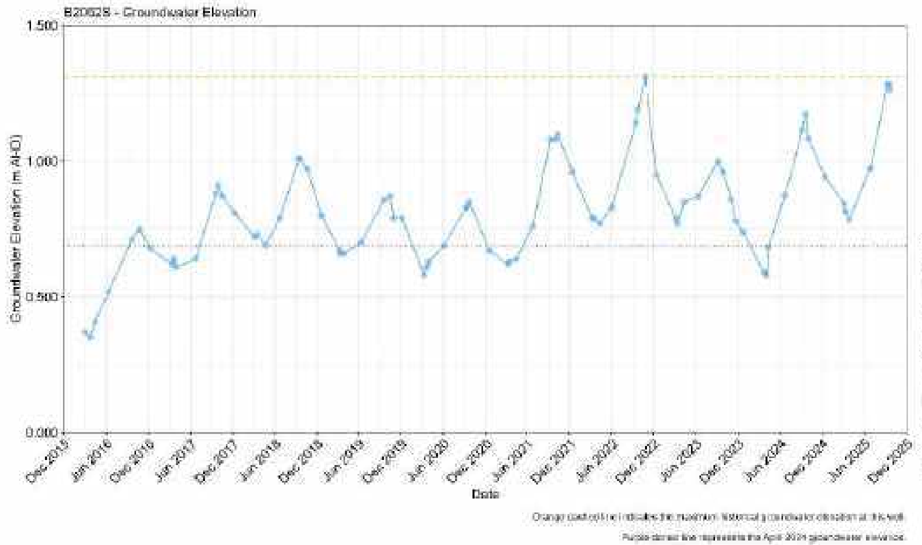
Purple dotted line represents the April 2024 groundwater elevation.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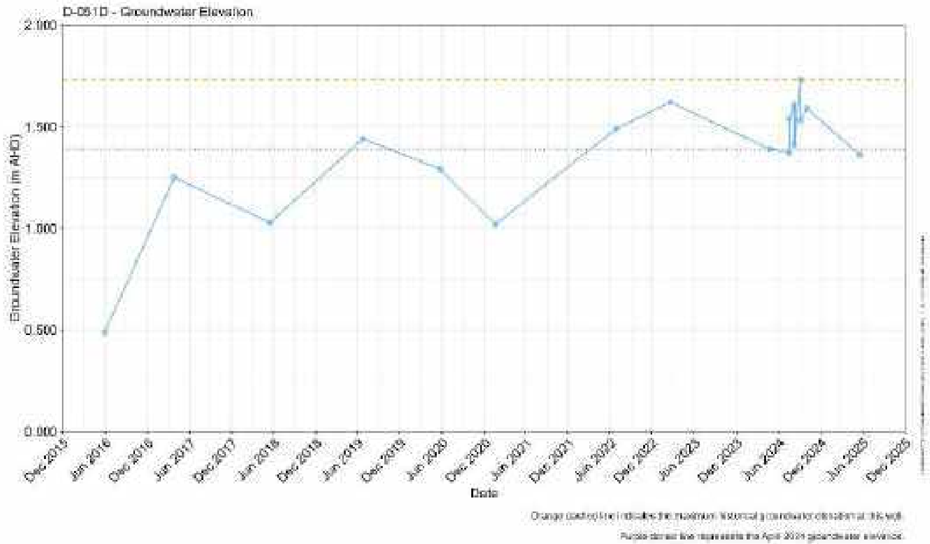
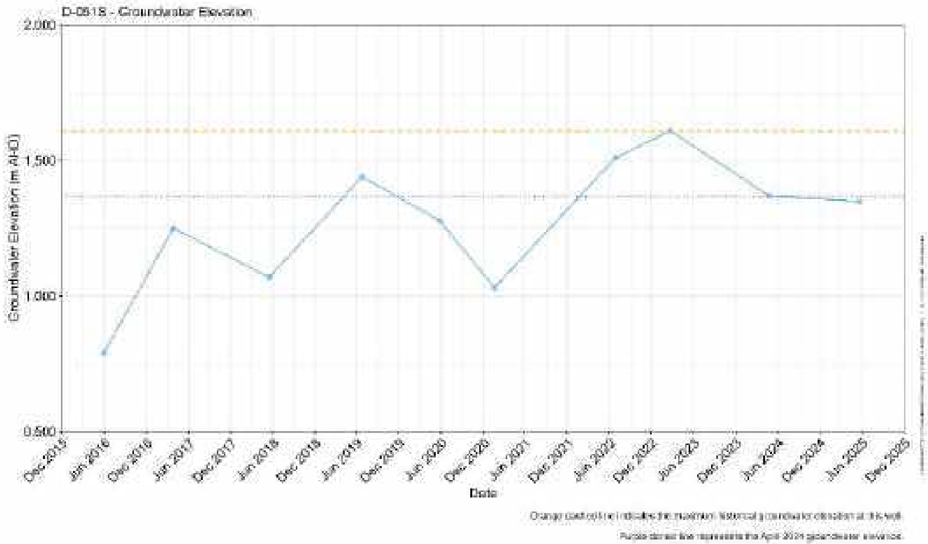
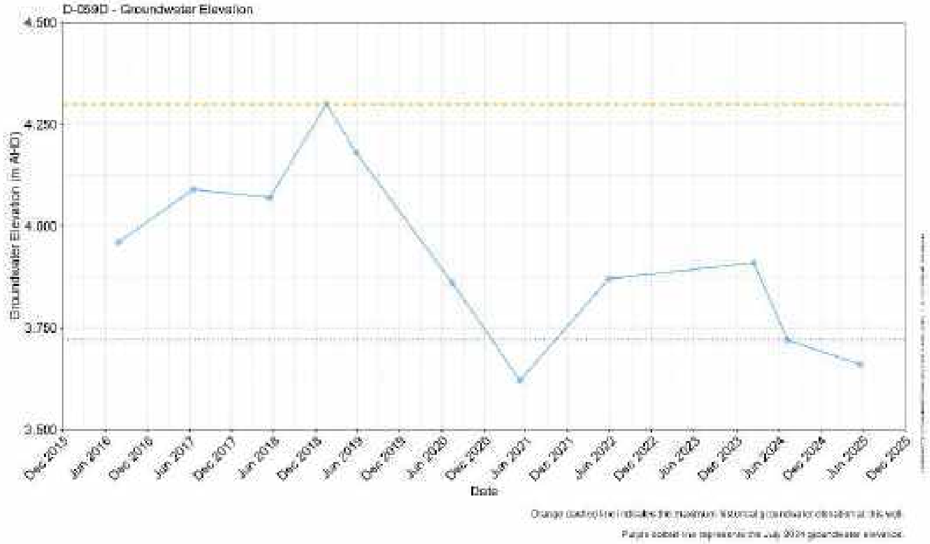
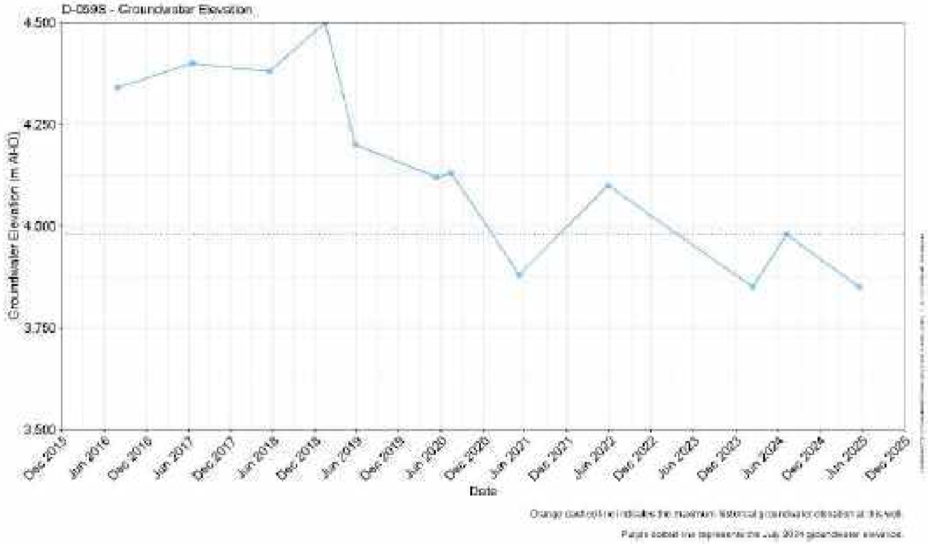
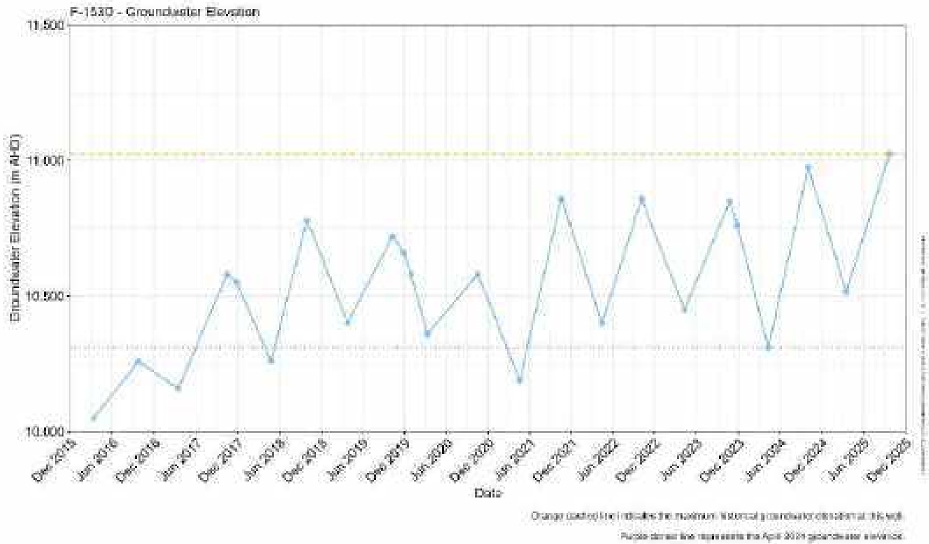
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.

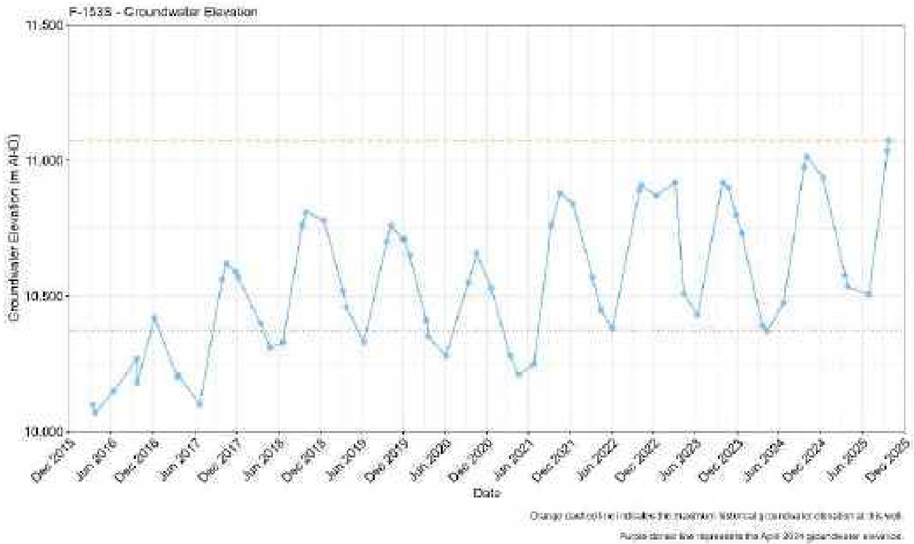

D-061D - Groundwater Elevation
Groundwater Elevation (m AHD)
2.000
1.500
1.000
0.500
0.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.

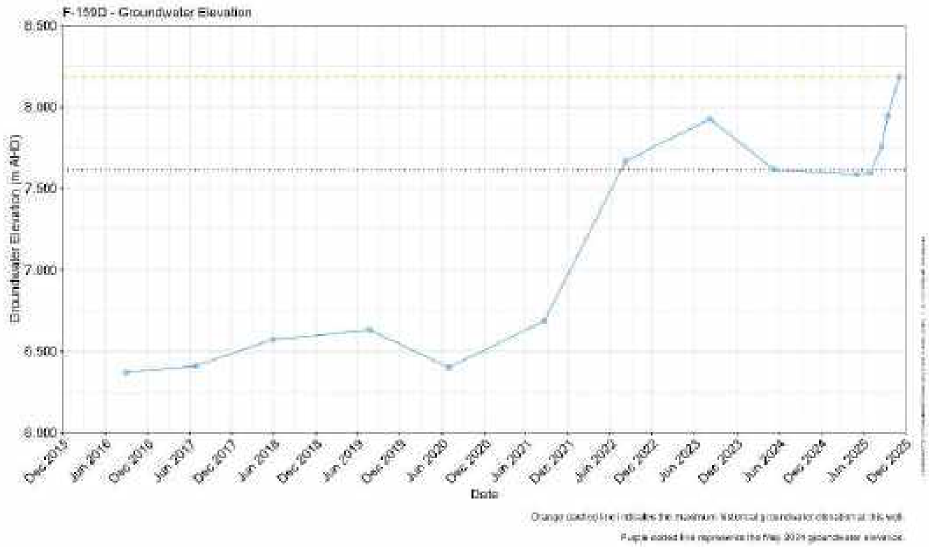

D-061S - Groundwater Elevation
Groundwater Elevation (m AHD)
2.000
1.500
1.000
0.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.

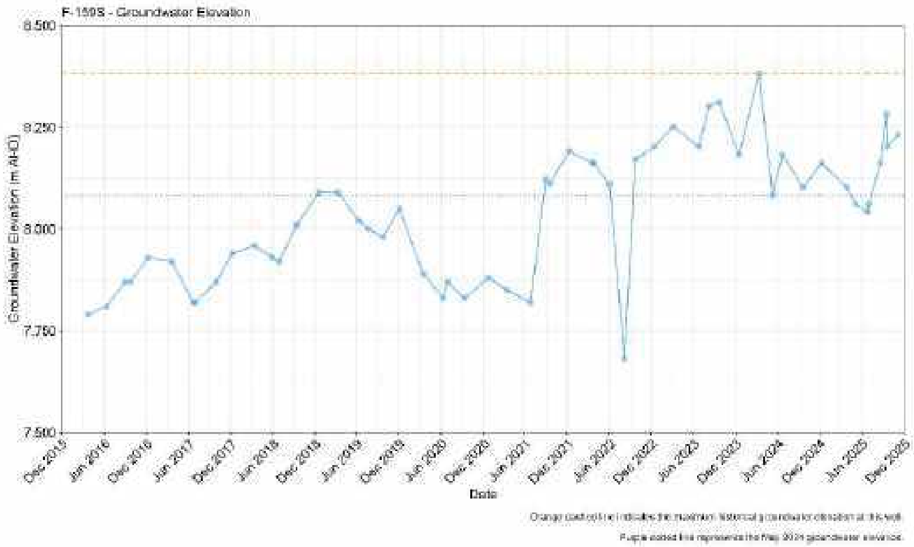

D-059D - Groundwater Elevation
Groundwater Elevation (m AHD)
4.500
4.250
4.000
3.750
3.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the July 2024 groundwater elevation.

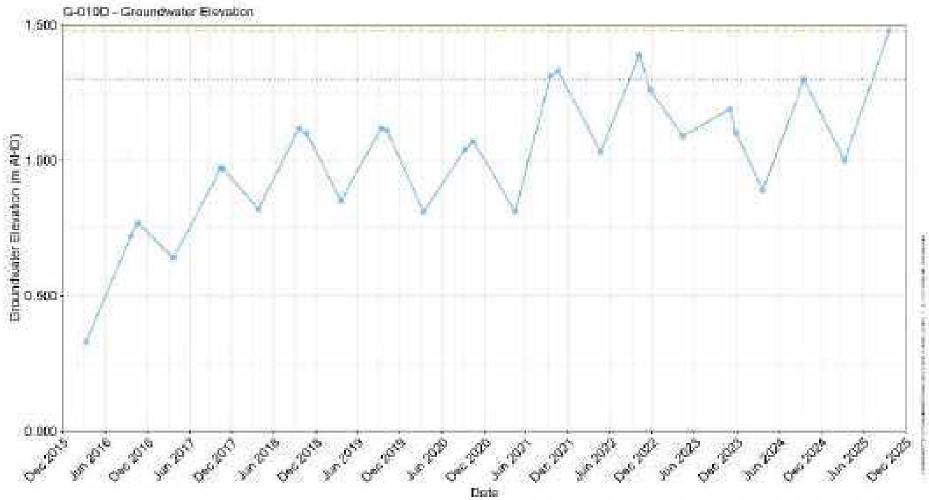

D-059S - Groundwater Elevation
Groundwater Elevation (m AHD)
4.500
4.250
4.000
3.750
3.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the July 2024 groundwater elevation.


F-153D - Groundwater Elevation
Groundwater Elevation (m AHD)
11.500
11.000
10.500
10.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.

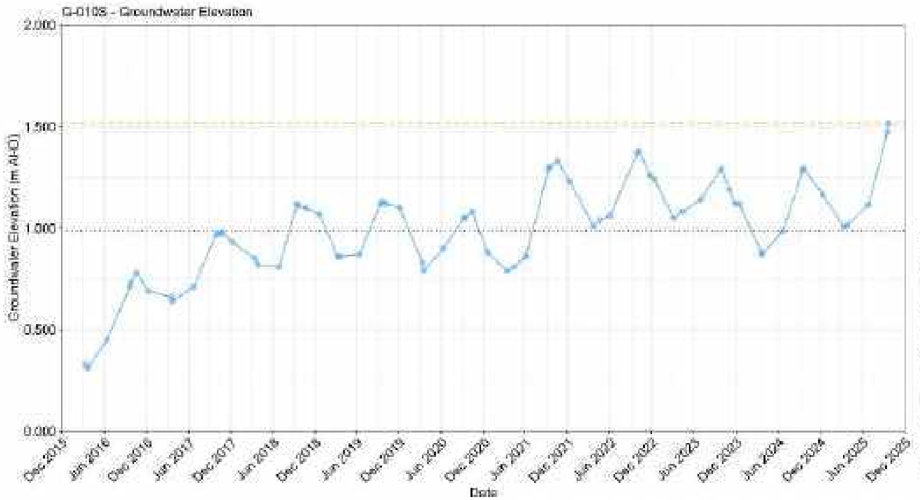

F-153S - Groundwater Elevation
Groundwater Elevation (m AHD)
11.500
11.000
10.500
10.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.


F-159D - Groundwater Elevation
Groundwater Elevation (m AHD)
8.500
8.000
7.500
7.000
6.500
6.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.

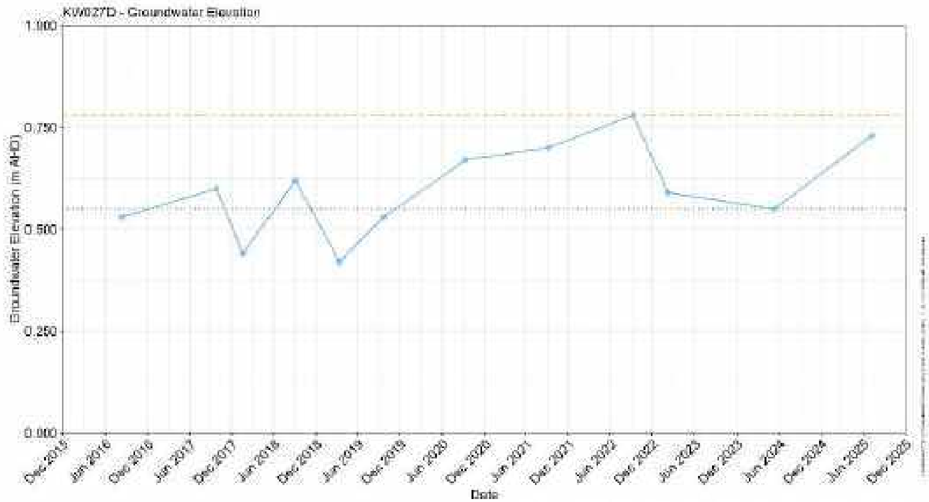

F-159S - Groundwater Elevation
Groundwater Elevation (m AHD)
8.500
8.250
8.000
7.750
7.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.



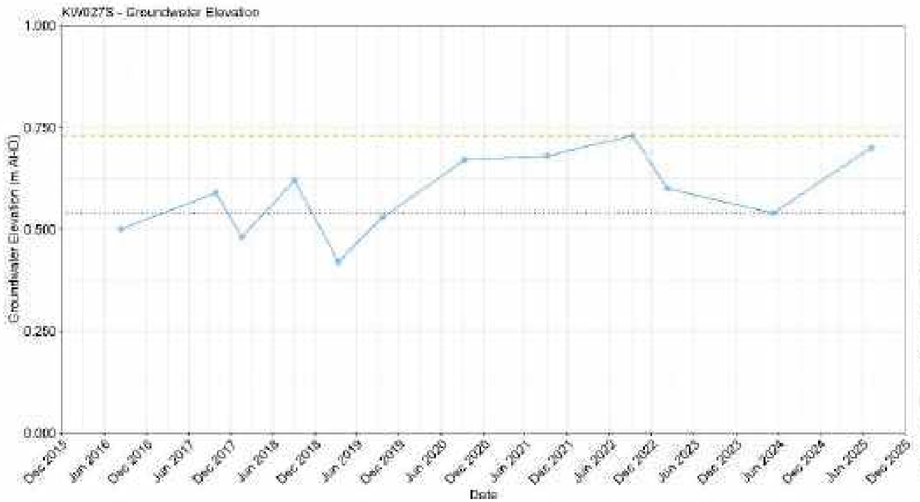
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the September 2024 groundwater elevation.



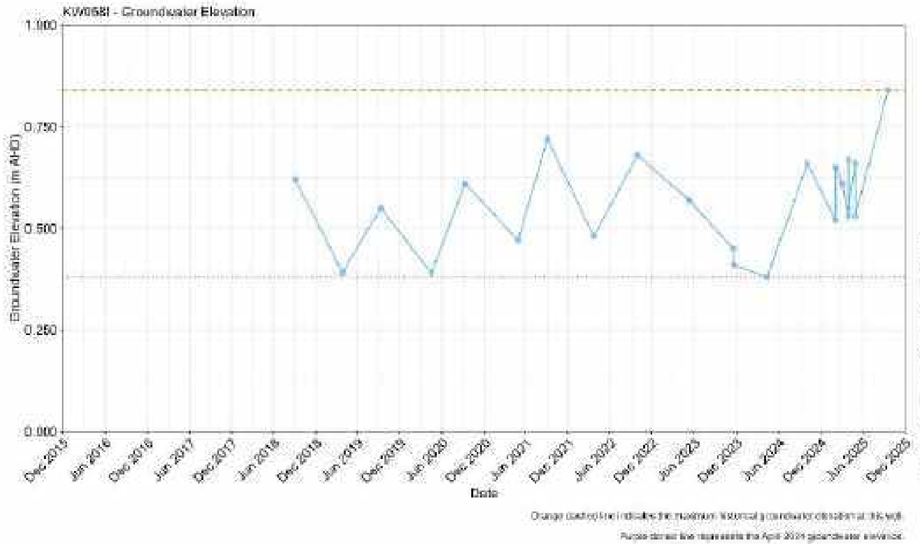
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the June 2024 groundwater elevation.

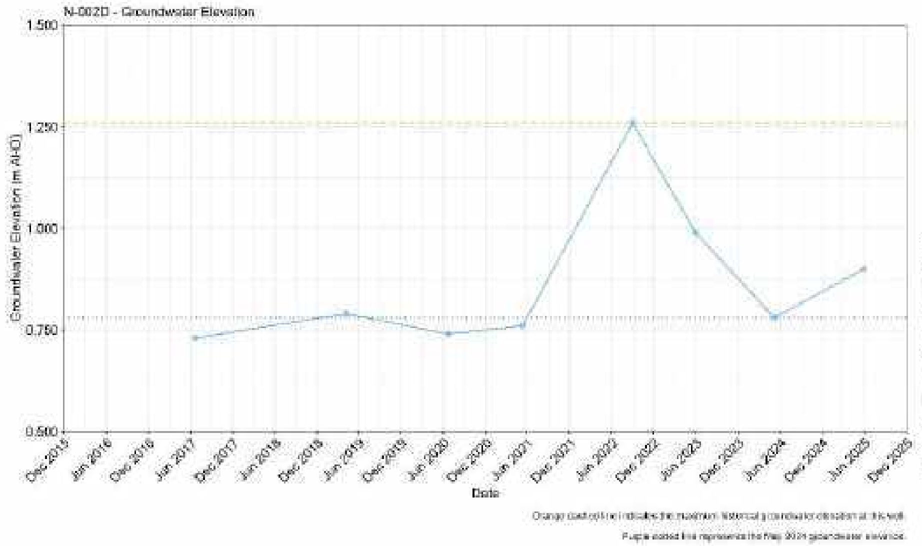


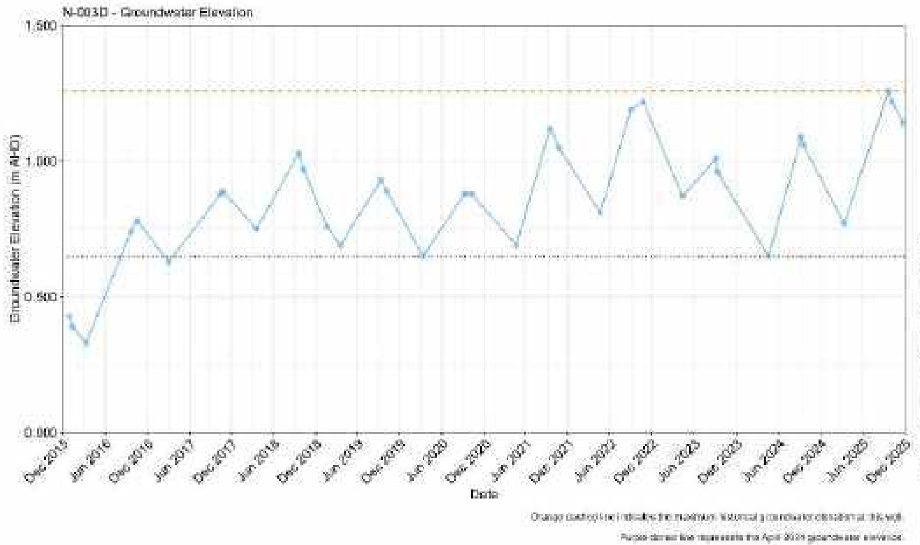
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.

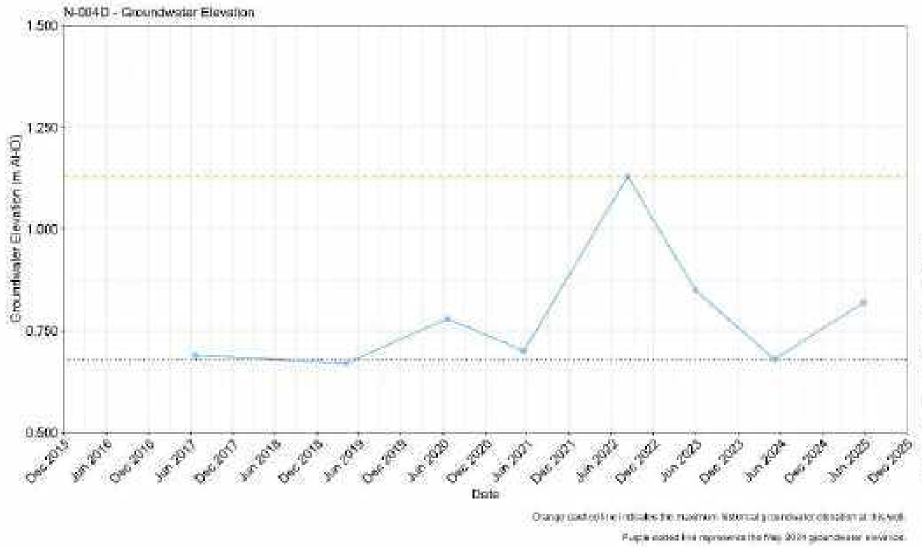


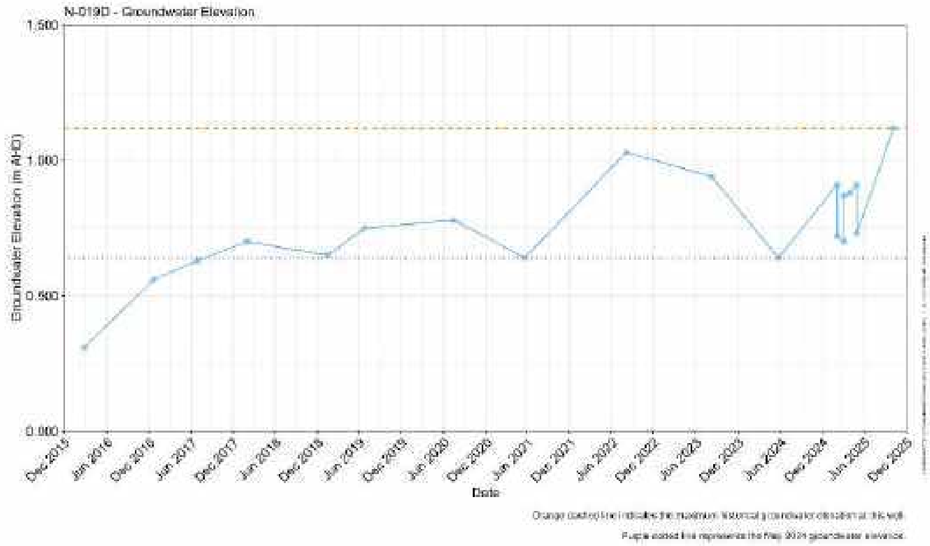
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.

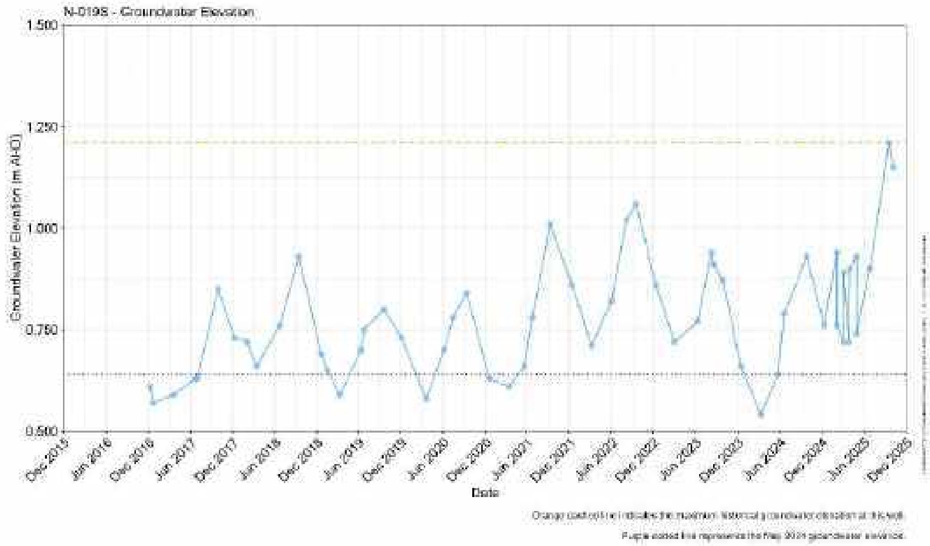

KW068I - Groundwater Elevation
Groundwater Elevation (m AHD)
1.000
0.750
0.500
0.250
0.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.


N-002D - Groundwater Elevation
Groundwater Elevation (m AHD)
1.500
1.250
1.000
0.750
0.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.


N-003D - Groundwater Elevation
Groundwater Elevation (m AHD)
1.500
1.000
0.500
0.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the April 2024 groundwater elevation.


N-004D - Groundwater Elevation
Groundwater Elevation (m AHD)
1.500
1.250
1.000
0.750
0.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.


N-019D - Groundwater Elevation
Groundwater Elevation (m AHD)
1.500
1.000
0.500
0.000
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.


N-019S - Groundwater Elevation
Groundwater Elevation (m AHD)
1.500
1.250
1.000
0.750
0.500
Dec 2015
Jun 2016
Dec 2016
Jun 2017
Dec 2017
Jun 2018
Dec 2018
Jun 2019
Dec 2019
Jun 2020
Dec 2020
Jun 2021
Dec 2021
Jun 2022
Dec 2022
Jun 2023
Dec 2023
Jun 2024
Dec 2024
Jun 2025
Dec 2025
Date
Orange dashed line indicates the maximum historical groundwater elevation at this well.
Purple dotted line represents the May 2024 groundwater elevation.