Appendix F Stage 2 Hotspot Reports

NORTHERN TERRITORY GOVERNMENT
Department of ENVIRONMENT, PARKS AND WATER SECURITY

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T 08 8924 4218

File reference
EN2011/0028-04~0216

19 May 2022

Ms Simone Saunders
Interim Chief Executive Officer
City of Darwin
GPO Box 84
DARWIN NT 0801

Dear Ms Saunders

Re: Issue of Authorised Officer Direction under the Waste Management and Pollution Control Act 1998

On 27 December 2021 the City of Darwin (CoD) notified the Northern Territory Environment Protection Authority (NT EPA) of a fire and localised smoke emanating from Stage 2 at the Shoal Bay Waste Management Facility (SBWMF). Mitigation strategies undertaken by CoD at the time involved smothering the fire with soil.

On 20 January 2022 and 15 March 2022 smoke was observed emanating from Stage 2 by authorised officers. The smoke was observed from points along the eastern batter at different locations to that reported on 27 December 2021.

Evidence supports that the actions taken by CoD since December 2021 have not extinguished the fire. Officers believe that the fire at SBWMF may continue to burn and cause harm and potential harm to the environment.

To address this risk we have issued authorised officer direction (**enclosed)** pursuant to section 72(k) of the Act. The direction requires CoD to prevent environmental harm and to manage wastes at Stage 2. To achieve this COD must engage a suitably qualified environmental consultant with demonstrated experience in identifying and managing landfill fires to advise CoD on specified actions they must take to reduce the potential for environmental harm caused by the fire.

If you have any questions about this correspondence please contact Kiara Ware on telephone (08) 8924 4218 or via email at kiara.ware@nt.gov.au.

Yours sincerely



Simon Gummer

Manager, Environmental Operations

Providing services for the

Northern Territory Environment Protection Authority

AUTHORISED OFFICER DIRECTION

(Issued pursuant to section 72(k) of the *Waste Management and Pollution Control Act 1998*)

Issued to: City of Darwin (ABN 11 503 313 301)

TAKE NOTICE THAT I, Kiara Ware an authorised officer for the purposes of section 70 of the *Waste Management and Pollution Control Act 1998* ("the Act"), have reason to believe that:

A) The City of Darwin (CoD) (ABN 11 503 313 301) is an occupier of Lot 03952, Town of Sanderson, also known as Vanderlin Drive, Holmes, Northern Territory 0812 ("the premises");

B) The premises is currently used as the Shoal Bay Waste Management Facility (SBWMF);

C) CoD as a licence holder is licensed to conduct certain activities at the premises subject to conditions of Environment Protection Licence (EPL) 188-03 which authorises CoD to:

   a. operate a premises for the disposal of waste by burial that service, or are designed to service, the waste disposal requirements of more than 1000 persons;

   b. collect, transport, store, re-cycle, treat or dispose of a listed waste (as per Table 1 of EPL 188-03) on a commercial or fee for services basis, other than in, or for, the purpose of a sewage treatment plant;

   c. operate a premises, other than a sewage treatment plant, associated with collecting, transporting, storing, re-cycling, treating or disposing of a listed waste (as per Table 1 of EPL 188-03) on a commercial or fee for service basis;

D) EPL188-03 requires CoD to:

   a. implement, maintain and follow an Emergency Response Plan that addresses procedures for responding to emergencies associated with the activity that may cause environmental harm;

   b. not cause or permit waste to be burned at the premises;

   c. maintain a log of fires occurring at the premises including the following:

      i. the time and date of when the fire was reported;

      ii. the circumstance which ignited the fire;

      iii. the time and date of when the fire ceased and whether it burnt out or was extinguished;

      iv. the location of the fire on the premises (e.g. timber stockpile, putrescible waste);

      v. prevailing weather conditions;

vi. observations made in regard to smoke direction and dispersion;

vii. the amount of waste combusted by the fire;

viii. action taken to extinguish the fire;

ix. measures taken to reduce the risk of further fire at the premises; and

d. notify the NT EPA of any incident at the premises causing or threatening to cause pollution including but not limited to fires.

E) On 27 December 2021, the Northern Territory Environment Protection Authority (NT EPA) was notified via email of a subterranean fire in Stage 2 of the landfill at the premises as shown in **Attachment A**;

F) At that time CoD advised that the fire was managed using *"a wet layer over the area to plug the location followed with heavier material being placed on top"*;

G) On 20 January 2022 authorised officers from the NT EPA conducted a site inspection and observed smoke being emitted from areas along the eastern batter of Stage 2. CoD were informed of the observation;

H) On 25 January 2022 CoD responded advising that they believed the fire had been extinguished when it had been originally reported on 27 December 2021 advising:

a. *"...City of Darwin believed that the fire had been extinguished to the best of our knowledge with no smoke to suggest otherwise"*;

b. *"The methodology being used currently is to smother and compact he area to reduce air flow and starve the fire of oxygen, then placing cover material over the top to create an airtight cap."*

I) On 11 March 2022 authorised officers from the NT EPA conducted a site inspection and detected odours consistent with a landfill fire in the north eastern area of Stage 2;

J) On 15 March 2022 authorised officers from the NT EPA conducted a site inspection and observed smoke, detected odours consistent with a landfill fire and recorded elevated concentrations of wastes or contaminants from emissions in the north eastern area of Stage 2;

K) On 15 March 2022, and previously, there were no warning signs or access restrictions observed by authorised officers on Stage 2. This was despite staff being present and heavy machinery operating on stage 2;

L) On 11 April 2022 CoD provided officers with a series of drone imagery including thermal flyover images of Stage 2 recorded at the end of March 2022. No other documentation or assessment of the imagery was provide;

M) Stage 2 is authorised to receive construction and demolition waste, fibrous and non-fibrous asbestos and waste tyres for disposal;

N) EPL188-03 does not permit the emission of wastes or contaminants to the air from Stage 2;

O) The NT EPA is aware that Stage 2:

a. is not a designed and engineered landfill in that it does not have discrete landfill cells nor is it lined with a liner or low permeability layer to control or reduce seepage of landfill leachate to groundwater;

b. landfill leachate is not able to be effectively intercepted or managed; and

c. generates landfill gas from the putrescible waste that had been buried below the non-putrescible waste currently being disposed of;

P) Gaseous emissions (including smoke) from landfills and land fill fires are wastes (as defined in the Act) and contaminants (as defined in the Act) and include potentially noxious matter;

Q) To date, insufficient evidence has been provided that confirms the fire first reported on 27 December 2021 has been extinguished;

R) To date, insufficient information has been provided that identifies the circumstance which ignited the fire or the measures taken to reduce the risk of further fire at the premises;

S) There is an immediate need to identify if the fire is still active at Stage 2 and to manage the impacts from the fire to prevent environmental harm;

T) Section 83 of the Act provides a number of offences for pollution incidents that cause environmental harm;

U) The Act defines environmental harm as:

"environmental harm" means:

(a) any harm to or adverse effect on the environment; or

(b) any potential harm (including the risk of harm and future harm) to or potential adverse effect on the environment, of any degree or duration and includes environmental nuisance.

V) Section 12 of the Act states that a person who:

a. conducts an activity that causes or is likely to cause pollution resulting in environmental harm or that generates or is likely to generate waste; or

b. performs an action that causes or is likely to cause pollution resulting in environmental harm or that generates or is likely to generate waste,

must take all measures that are reasonable and practicable to:

c. prevent or minimise the pollution or environmental harm; and

d. reduce the amount of the waste;

AUTHORISED OFFICER DIRECTION

W) The Act defines environment as land, air, water, organisms and ecosystems and includes well-being of humans; structure or modified by humans; amenity values of an area; and economic, cultural and social conditions.

AND I HEREBY DIRECT City of Darwin (ABN 11 503 313 301) pursuant to section 72(k) of the *Waste Management and Pollution Control Act 1998* to:

1) To **immediately** prevent environmental harm by:
    a) preventing any further disposal of any wastes on areas within Stage 2 where there is evidence of fire, subsidence or emission points of gas, smoke or heat; and
    b) preventing staff, machinery, visitors and members of the public from entering any areas of Stage 2 where there is evidence of fire, subsidence or emission points of gas, smoke or heat;
2) By **15 June 2022** engage a suitably qualified environmental consultant with demonstrated experience in identifying and managing landfill fires to:
    a) By **1 July 2022**:
        i. confirm the location and extent of any subterranean fire in Stage 2;
        ii. confirm the location and extent of all areas of Stage 2 impacted by the fire identified on or occurring since 27 December 2021;
        iii. identify if any exclusion zones are required at Stage 2 and beyond, to prevent further environmental harm occurring (including to the well-being of humans working at or visiting the site);
    b) By **15 August 2022** develop a strategy to extinguish any subterranean fires remaining at Stage 2. The strategy should include but not be limited to:
        i. Methodologies and timelines for extinguishing the subterranean fire;
        ii. Site layout detailing the proposed approach;
        iii. Environmental management plan (including proposed monitoring);
        iv. Monitoring plan to determine success or otherwise; and
        v. Emergency response plan;
    c) By **30 August 2022** develop and commence implementation of a monitoring program to:
        i. investigate the presence and extent of contaminants associated with the subterranean fire in Stage 2; and
        ii. develop a preliminary assessment of the extent and actual and potential environmental harm from the subterranean fire on air quality, surface water quality and groundwater quality at the premises and on sensitive receptors to the premises;

AUTHORISED OFFICER DIRECTION

3) Within 7 days following each deadline for requirements 2, 2a), 2b) and 2c) above, provide details of City of Darwin's compliance with the requirements of this direction to the NT EPA by emailing waste@nt.gov.au.



19 May 2022

Authorised Officer **Date**

Northern Territory Environment Protection Authority

Important Notice

Failure to comply with the lawful requirements of an authorised officer is an offence under section 76(c) of the *Waste Management and Pollution Control Act 1998* and may incur significant penalties and/or other statutory action.

This notice takes effect on the date on which it is served upon you.

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ATTACHMENT A – Aerial Image of Stage 2 and location of reported fire



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Design
for a better
future /

City of Darwin

Shoal Bay: Waste Management Facility

Preliminary Landfill Hotspot Risk Assessment

November 2023

Question today
Imagine tomorrow
Create for the future

Shoal Bay: Waste Management Facility
Preliminary Landfill Hotspot Risk Assessment

City of Darwin

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Rev	Date	Details
A	13 July 2023	Final
B1	14 November 2023	Draft
C	28 November 2023	Final

	Name	Date	Signature
Prepared by:	Domi Diaz, **Amy MacGregor**, Christin Down, Carl van Brink	28 November 2023	
Reviewed by:	Bruce Dawson	28 November 2023	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

This document may contain confidential and legally privileged information, neither of which are intended to be waived, and must be used only for its intended purpose. Any unauthorised copying, dissemination or use in any form or by any means other than by the addressee, is strictly prohibited. If you have received this document in error or by any means other than as authorised addressee, please notify us immediately and we will arrange for its return to us.

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1 Introduction

1.1 General

The City of Darwin (CoD) council engaged WSP Australia Pty Ltd (WSP) to conduct a preliminary assessment of risk associated with sub-surface hotspots within waste at the Shoal Bay Waste Management Facility (SBWMF). This preliminary risk assessment considers the potential for receptors to be impacted by contaminants associated with sub-surface hotspots.

The report should be considered preliminary in nature as conclusions regarding risk will be dependent on the nature and extent of sub-surface hotspots within the landfill. Data regarding temperatures within the landfill are still being gathered and the conclusions in this report may need to be revised following collection of additional data and as the understanding of the nature and extent of the hotspots is developed.

1.2 Objective

The objective of the preliminary risk assessment is to assess the potential risk of harm to the water and air environment as associated with the impacts of sub-surface hotspots within the landfill site. A review of the air quality, sub-surface temperatures, groundwater and surface water monitoring data has been undertaken. The monitoring data was used to assess changes, trends and the potential for human health and the environment to be impacted from the sub-surface hotspots. This preliminary assessment is not intended to provide an assessment of the overall impacts of the landfill operations on the environment but is limited to consideration of subsurface hotspots only.

1.3 Background

The CoD holds Environment Protection Licence EPL188-03 (the Licence), issued by the Northern Territory under the *Waste Management and Pollution Control Act 1998* (WMPC Act), for the operation of the SBWMF. Licence EPL188-03 replaced Licence EPL12-08. The CoD leases the property from the Commonwealth Department of Defence. Under the conditions of the lease, the property is designated as a Waste Management Project Area in which CoD is authorised to conduct waste management and ancillary activities. SBWMF is the main waste resource recovery and disposal site servicing domestic and commercial customers in the Darwin area.

Environmental investigations conducted at SBWMF include:

- a hydrogeological investigation undertaken by URS on 26 November 2015 (URS, 2015)
- a conceptual site model developed on 26 February 2016 (URS, 2016a)
- a water monitoring plan developed on 21 March 2016 (URS, 2016b)
- an ecological risk assessment issued on 21 March 2016 (URS, 2016c)
- a water quality monitoring data review prepared on 12 August 2020 (EcOz, 2020a)
- the environmental management plan updated on 12 August 2020 (EcOz, 2020b)
- air quality monitoring undertaken in September 2022
- sub-surface temperature monitoring undertaken by measuring downhole standpipe temperatures across the SBWMF since August 2022.

Groundwater, surface water, and landfill leachate water quality monitoring is required to be undertaken in accordance with the conditions of EPL188-03 and the Shoal Bay Disposal Site Water Monitoring Plan (URS, 2016b).

In December 2021 the CoD became aware of the presence of sub-surface hotspots, indicated by:

- venting from the landfill surface
- presence of odour similar to burning timber
- small areas of subsidence noticed in the surface mid-way along the eastern batter of stage 2.

The CoD advised the NT EPA of the sub surface hotspots on 27 December 2021. The NT EPA issued an Authorised Officer Direction pursuant to Section 72(k) of the *Waste Management and Pollution Control Act 1998* on 19 May 2022. The Direction required CoD to:

- prevent environmental harm
- engage a suitably qualified environmental consultant to confirm the location and extent of hotspots and identify exclusion zones
- develop a strategy to extinguish sub-surface hotspots
- develop and implement a monitoring program.

1.4 Information sources

Assessment reports and monitoring data relating to the site used in this report include:

- Shoal Bay Waste Management Facility: Hydrogeological investigation (URS, 2015),
- Shoal Bay Waste Management Facility: Conceptual Site Model (URS, 2016a),
- Shoal Bay Disposal Site Water Monitoring Plan (URS, 2016b),
- Shoal Bay Waste Disposal Site Ecological Risk Assessment (URS, 2016c),
- Environmental Management Plan: Shoal Bay Waste Management Facility Rev.2 (EcOz, 2020).
- Shoal Bay Waste Management Facility: Water Quality monitoring data review 2016-2020 (EcOz, 2020)
- SBWMF Environmental Monitoring Database: Groundwater, surface water and leachate monitoring data 1986-2022 (CoD, 2022)
- Standpipe temperature monitoring data August 2022 – May 2023
- Ambient Air Quality Monitoring Shoal Bay Waste Management Facility (WSP, 2022)

Previous consultants reports are presented in Appendix A and summarised below:

Shoal Bay Waste Management Facility: Hydrogeological investigation (URS, 2015)

URS prepared a hydrogeological investigation to summarise the regional geology, hydrogeology and hydrology of the Darwin area. The report details the aquifer types and properties and groundwater quality, groundwater levels and groundwater flow directions.

Environmental Management Plan: Shoal Bay Waste Management Facility Rev.2 (EcOz, 2020).

EcOz Pty Ltd. developed an Environmental management plan (EMP) to detail the environmental management measures undertaken at SBWMF to minimise the potential for impacts to the surrounding environment.

Specifically, it identifies the risks to the environmental associated with the activities at SBWMF, and details the environmental management measures, controls and monitoring that will be implemented by all staff and contractors operating within the site.

The EMP has been developed to comply with the relevant environmental legislation; and to adhere to conditions of any applicable licence approval and permit.

Shoal Bay Waste Management Facility: Water Quality monitoring data review 2016-2020 (EcOz, 2020)

EcOz Pty Ltd. prepared a water quality monitoring data review to achieve the following:

- Summarise the leachate, surface water, and groundwater monitoring activities undertaken from July 2016 to March 2020;
- Analyse the monitoring data and highlight the trends occurring for the three water types (leachate, surface water and groundwater), with particular consideration for indications of leachate ingress, or deteriorating water quality in certain areas of SBWMF;
- Discuss the potential environmental impacts to surface and groundwater, and receiving offsite environments;
- Discuss the implications of these water quality monitoring results for improving water and leachate management at the SMWMF, and
- Review the ongoing water quality monitoring program and suggest improvements.

SBWMF Environmental Monitoring Database: Groundwater monitoring 1986-2022 (CoD, 2022)

WSP undertook a review of groundwater and surface water monitoring data.

Additionally WSP has gathered additional information and prepared a reports:

Standpipe temperature monitoring data August 2022 – May 2023

WSP undertook a review of standpipe temperature monitoring data.

Ambient Air Quality Monitoring Shoal Bay Waste Management Facility (WSP Golder Ref PS132331-011-R-Rev0, 6 December 2022) (supplied as Appendix B).

1.5 Exclusions to the environmental investigation scope

The current environmental investigation is focused on the assessment of the risk of possible harm caused by the generation emissions or discharges associated with sub-surface hotspots in the landfill. The environmental investigation does not include an assessment of impacts associated with historical surface fires and non-sub-surface hotspots impacts associated with landfill operation or a total assessment of the site to determine suitability for future use of the Site or surrounding areas.

2 Site setting

2.1 Location

SBWMF is located approximately 12 km north-east of Darwin city. The SBWMF lies within Lot 3952, Town of Sanderson. The CoD leases the property area from the Commonwealth Department of Defence. Under the terms and conditions of the lease, the property is designated as a Waste Project Area in which CoD is authorised to conduct waste management and ancillary activities.

2.1.1 Waste disposal

The Stage 2 landfill comprises an Inert Waste Cell overlying a General Waste Cell. It is understood that both the inert and general waste landfills were constructed and operated without installed engineered leachate containment liners and collection systems. The inert waste depth is understood to be up to approximately 15 m deep, and the historical general waste below is thought to be 10 to 15 m deep. Maximum depth of waste could therefore be in the order of 25 m to 30 m. Our understanding is that there are no comprehensive records available relating to historical waste deposition and depth.

2.1.2 Surrounding land use

The SBWMF is surrounded by bushland, floodplains, wetlands, and mangroves to the north, east, and west. The Holmes Jungle Nature Park is located to the south. The nearest residential area to the SBWMF is the suburb of Karama, about 1 km to the south-west with a bushland buffer in between.

2.2 Hydrogeological and hydrological setting

2.2.1 Geology

Lithology encountered during the hydrogeological investigation (URS, 2015), consisted of topsoil (silts and clays), generally underlain by weathered siltstone, with claystone encountered east of Stage One. Sandstone was encountered at approximately 9 metres below ground level (mbgl) to 20 mbgl across the site in bores drilled down to 30 mbgl. No identified karst or limestone strata was encountered in the hydrogeological investigation (URS, 2015).

2.2.2 Regional hydrogeology

Groundwater aquifers beneath the site are described in the Shoal Bay Waste Disposal Site, Hydrogeological Investigation (URS 2015), which draws on the Water Resources Map of Darwin (1:100,000, Map Sheet 5073 Edition 2) and the Hydrogeological Map of Darwin Explanatory Notes (1:250,000 Scape Map). Information from URS (2015a) is summarised as follows:

There are two main aquifer types in the Darwin:

- **Fractured and weathered carbonate aquifers.** Carbonate rocks comprise the major aquifers in the Darwin region. Yields in excess of 5 L/sec are not uncommon: the McMinns Hydrostratigraphic Unit, the Dolomite or Carbonate Layer in the Middle Proterozoic-age rocks, and the Coomalie/Koopinya dolomites are aquifers that have historically been used for water supply and agriculture.
- **Fractured and weathered non-carbonate aquifers**. Bore yields in these aquifer types are variable, ranging from 0.5 L/sec (‘minor’) to 10 L/sec (‘medium’). Groundwater may be encountered within unconfined Quaternary sediments and fractured, weathered underlying bedrock. The groundwater resources in the area are classified as ‘minor’ with generally low bore yields (less than 0.5L/sec), but higher yields with lower aquifer storage may occur in sand lenses within the Quaternary sediments, gravel layers that may be present at the interface of sediments, and fracturs and quartz veins with the bedrock.

The Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region map (NRETA 2008) identifies a high yielding carbonate aquifer south-east of the SBWMF, trending in a northerly direction. Groundwater from this aquifer discharges to the surface within the Holmes Jungle Nature Park and maintains streamflow through the dry season. The Holmes Jungle Nature Park springs and associated shallow groundwater support the Holmes Jungle rainforest. Further to the south-east around the Knuckey Lagoon area, a large number of bores draw groundwater from this carbonate aquifer for domestic and agricultural purposes.

The carbonate rock aquifer and associated springs, Holmes Jungle rainforest and groundwater users are all located up gradient of the SBWMF.

2.2.3 Site hydrogeology

Lithology encountered during groundwater bore drilling for the investigation comprised topsoils (silts and clays), generally underlain by weathered (lateritised) siltstone over most of the site, and claystone across most of the site.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. Seasonal groundwater standing water levels (SWLs), measured as part of the SBWMF water quality monitoring program since 2016, are greater than 12 mbgl at the end of the dry season, and usually less than 2mbgl during the peak of the wet season.

Groundwater down gradient of the SBWMF is saline due to its proximity to the coast and tidal saline intrusion (Groundwater Resources of the Darwin Area map (DIPE 2003)). There are no identified groundwater bores or groundwater users down gradient of the SBWMF (EcOz, 2020a). Groundwater seepage occurs into wetlands and tidal inlets during the dry season.

No significant areas of carbonate rock aquifer are located down gradient of the SBWMF and no carbonate rocks were encountered when drilling the 32 groundwater bores, to depths of up to 30 mbgl, across the site for the hydrogeological investigation (URS 2015).

The Shoal Bay Waste Disposal Site Conceptual Site Model (URS 2016b) provides further analysis of potential contamination pathways for leachate and other pollutants from the SBWMF towards human health and environmental receptors.

2.2.4 Hydrology

Surface water from the eastern portions of the SBWMF flows towards the Mickett Creek floodplain. Flows from the western portion of the site are towards the Leanyer Swamp and Buffalo Creek. Both Mickett Creek and Buffalo Creek are mangrove-lined tidal inlets of Shoal Bay, a coastal embayment with extensive sand and mud flats.

The SBWMP Environmental Management Plan (CoD 2016), Section 5.6 Water Quality Management provides further information on surface water flows and water management across the site.

2.3 Conceptual site model

A conceptual site model (CSM) has been prepared by URS Australia Pty Ltd in February 2016 (URS, 2016). Potential sources of emissions and discharges associated with sub-surface landfill hotspots, migration pathways and identified receptors is schematically illustrated in Figure 2.1.

2.3.1 Potential migration pathways

Potential migration pathways to groundwater and surface water systems associated with sub-surface hotspots in the landfill include:

- Leachate migration through the landfill; and
- Potentially leachate-impacted surface water runoff from leachate seeps within the landfill;

Potential migration pathways for emissions or discharges associated with sub-surface hotspots in the landfill include:

- Emissions from current hotspots in sub-surface waste at the landfill to air. Historic currently inactive sub-surface hotspots are considered to have an incomplete pathway to air given their absence of emissions;
- Migration of constituents associated with both current and historic sub-surface hotspots via erosion or leaching into surface runoff transported to surface waters; and
- Leaching of constituents associated with both current and historic sub-surface hotspots into groundwater and discharge to surface water.

2.3.2 Receptors

Potential sensitive receptors are described in Table 2.1:

Table 2.1 Potential sensitive receptors

	Receptors
Air	— Life, health and well-being of humans — Life, health and well-being of other forms of life, including the protection of ecosystems and biodiversity — Local amenity and aesthetic enjoyment (visibility, useful life and aesthetic appearance of buildings, structures, property and materials) — Climate systems that are consistent with human development, the life, health.
Water	— The waters of the floodplain east and west of the site (Mickett Creek and Buffalo Creek floodplains respectively) and their flora and fauna ecosystems — Agriculture, aquaculture, public water supply, environment, culture, industry, rural stock and domestic, mining activity and petroleum activity.

2.3.3 *Schematic – Source, pathways, and receptors for sub-surface hotspot emissions and discharges migration*

The schematic CSM provided in Figure 2.1 outlines the potential pathways for contaminant migration to receptors from the landfill.

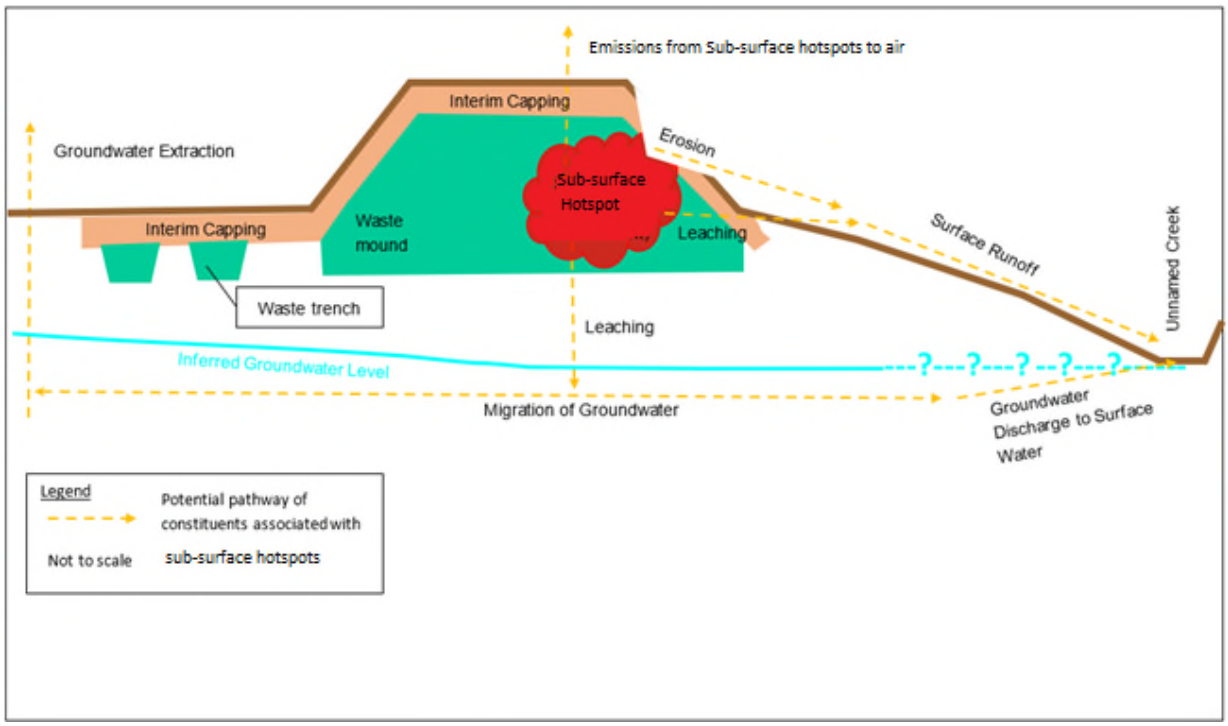


Figure 2.1 Conceptual site model (URS, 2016a)

2.4 Sub-surface landfill hotspots

There are a variety of possible initial causes for the development of sub-surface landfill hotspots. The burial of hot waste or combustible material can develop into hotspots. Natural decomposition processes can also generate a build-up of heat. This can lead to hotspots if the temperature is high enough. Additionally, exposure to oxygen or an ignition source (such as batteries sparking) can also lead to hotspots. Surface fires are also considered as possible initial cause of sub-surface hotspots. Sub-surface landfill hotspots can occur for years before they are detected (UK Environment Agency, 2007a).

Whilst it has been recognised that hotspots can "significantly harm the environment due to the emissions of toxins into the atmosphere, soil and water" (Vaverková, 2019), often literature has not delineated between the environmental impact of surface and sub-surface landfill fires. The term "landfill fire" is often used to include surface and sub-surface (or deep-seated) landfill fires (UK Environment Agency, 2007b).

2.5 Landfill contaminants of interest (COI)

The assessment of the potential impact of landfill sub surface hotspots requires consideration of typical COIs in the absence of sub-surface hotspots. Guidelines such as the UK Environment Agency's (2004 a & b) *Hydrogeological Risk Assessments for Landfills* and *Guidance on the Management of Landfill Gas* provide information as to the COIs within various media such as air, groundwater, surface water and land. The following sections provide a summary of typical COIs when assessing the impact of landfill operations on the environment.

2.5.1 Air

There are a variety of potential air pollutants in addition to potential nuisance odour. Nuisance odour can be transported from the source by (Environment Agency 2004b):

- The emissions of dust and odours;
- Wind-blown material;
- Noise and traffic;
- Birds, vermin and insects;
- The formation of aerosols;
- Fires.

Table 2.2 (bulk compounds) and Table 2.3 (trace components) describe typical landfill gas COIs. Table 2.3 does not cover the full scope of trace gases, where around 550 trace compounds belonging to a variety of chemical groups have been identified in landfill gas (UK Environment Agency, 2004b).

Table 2.2 Bulk compounds in landfill gas (UK Environment Agency, 2004b)

Bulk landfill gas	Typical value (% w/w)
Methane	63.8
Carbon dioxide	33.6
Oxygen	0.16
Nitrogen	2.4
Hydrogen	0.05
Water vapour (typical % w/w, 25°C)	1.8

Table 2.3 Some trace components of landfill gas (UK Environment Agency 2004b)

Name	Chemical group
Butan-2-ol	Alcohols
n-butane	Alkane
n-hexane	Alkanes
n-nonane	Alkanes
Toluene	Aromatic hydrocarbons
Ethylbenzene	Aromatic hydrocarbons
Xylene	Aromatic hydrocarbons
Carbon monoxide	Carbon Monoxide
α-pinene	Cycloalkenes 2
1,1-Dichloroethane	Halogenated organics
Chlorobenzene	Halogenated organics
1,1,1-Trichloroethane	Halogenated organics
Chlorodifluoromethane	Halogenated organics
Tetrachloroethene	Halogenated organics
Chloroethane	Halogenated organics
Chloroethene	Halogenated organics

Name	Chemical group
1,2-Dichlorotetrafluoroethane	Halogenated organics
cis-1,2-Dichloroethene	Halogenated organics
Dichlorofluoromethane	Halogenated organics
Dichloromethane	Halogenated organics
1,2-Dichloroethane	Halogenated organics
3-Methyl-2-butanone	Ketones
Hydrogen sulphide	Reduced Sulphur compounds

2.5.2 *Surface waters and groundwater*

Landfill leachate and its potential effects on land and groundwater from landfills is well understood. This landfill is not lined, which increases the potential for leachate to be transported into surface water and groundwater systems.

Table 2.4 describes chemical species that may be appropriate to consider as COIs in typical domestic (non-hazardous MSW) landfills (UK Environment Agency, 2004a).

Table 2.4 Potential chemicals present in typical domestic (non-hazardous MSW) landfills

Category of parameter	Examples
Metals	Arsenic, cadmium, chromium (vi), copper, lead, mercury, molybdenum, nickel, tin, selenium, silver, and zinc
Organic species	— Phenols (halogenated) — Phenols (non-halogenated) — Monocyclic aromatic hydrocarbons — Benzene — Polyaromatic hydrocarbons – Naphthalene and Benzopyrene — Benzo(a)pyrene — C_6–C_9 petroleum hydrocarbons — C_{10}–C_{36} petroleum hydrocarbons — Polychlorinated biphenyls — Chlorinated hydrocarbons — C_1-C_4 dissolved gases
Herbicide	Organochlorine pesticides: — Aldrin + dieldrin — DDT + DDD +DDE — Chlordane — Heptachlor
PFAS	Perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and perfluorohexane sulfonate (PFHxS)
Cations, anions, nutrients, physical and inorganic parameters	— Major cations and anions — Un-ionised hydrogen sulfide — Nutrients including total nitrogen, nitrate, nitrite, ammonia as N, and total phosphorus — Total dissolved solids — CO_2 free and total — Volatile fatty acids

2.6 Sub-surface hotspots contaminants of interest (COI)

The conditions of potential sub-surface hotspots will likely be anoxic which would lead to the pyrolysis of municipal solid waste (MSW). Pyrolysis may potentially lead to emissions of organic contaminants of interest (COIs) to air, surface and groundwater, and land. The amount and nature of contaminants that will be generated as a result of hotspots and subsequently move through the environment is dependent on the temperature of pyrolysis, the composition of the waste, and other conditions affecting the reaction.

Pyrolysis may produce a range of COIs depending on specific conditions such as the hotspot temperature ranges, heating rate, residence time, material size and composition, MSW characteristics, humidity, water and oxygen availability, and other factors (Chen et al 2014; Martìn-Lara et al 2021). As the identified literature has not focused on the pyrolysis of waste in sub-surface hotspots, much of the following information regarding COIs has been derived from information available on the pyrolysis of specific waste streams in controlled conditions. For example, with the pyrolysis of plastic MSW, the majority of COIs will produce as liquids and gases, with a small amount of char remaining in the land (Chen et al, 2014). Notwithstanding, the primary COIs associated with sub-surface hotspots are likely to be the same as those usually present in landfills; however, the amount of these COIs produced during sub-surface hotspots is highly dependent on the site specific conditions associated with the sub surface hotspots (e.g., extent, duration, waste types).

In addition to direct effects of pyrolysis of PFAS-containing waste, on-site firefighting activities of sub-surface hotspots at the landfill using aqueous film forming foam (AFFF) may be a point source for PFAS contamination. Information provided by CoD indicates that AFFF has not been used at the site for fire suppression.

2.6.1 Air

For sub-surface hotspots (pyrolysis), the combination of anoxic conditions and low temperatures will produce a variety of gases which may contain (Vaverková, 2019):

- Dioxins and furans
- PAHs and organic compounds
- Particulate matter
- Heavy metals.

The product yields of gases from various controlled pyrolysis reactions range from 8 – 34% (Chen et al 2014). A study from Miskolczi et al (2013) found that gaseous contaminants such as S, Cl, and Br, in addition to trace[1] contaminants such as K, S, P Cl, Ca, Zn, Fe, Cr, Br, Sb, and Pb, occurred during the pyrolysis of MSW and municipal plastic waste (MPW). It is likely that a range of other compounds including organics may be produced during pyrolysis but may not have been measured due to the focus of their research.

2.6.2 Groundwater and surface water

Pyrolysis of chlorine-containing compounds is associated with the realise of dioxins and furans in air, as mentioned in Section 2.6.1. However, a literature review (Millrath 2004) on the leaching of dioxins and furans from residues of municipal waste combustors states that:

> *"analytical results from reviewed studies showed that dioxins/furans … leachates contained [dioxins/furans] at concentrations below the allowable drinking water standards level of 30 ppt"*

And;

> "leachates [containing dioxins/furans at ash disposal sites from waste-to-energy ash] do not pose a public health threat".

It is therefore considered that dioxins and furans are not a COI requiring specific assessment in this case.

[1] These contaminants were found in water used to scrub the gas, hence, they have been described as trace contaminants

3 Methodology

3.1 Desktop review

A desktop review of air quality, groundwater, and surface water monitoring data was undertaken to detect if contaminants from the landfill, specifically associated with sub-surface hotspots, are present in the air, groundwater or surface water. A review of the sub-surface temperature monitoring was undertaken to evaluate the nature and extent of the sub-surface hotspots.

3.2 Investigation methodology

The adopted methodology for investigation included the following:

1 **Familiarisation and Preliminary Document Review**: site information and relevant information found in past reports and investigations were reviewed.

- **Groundwater monitoring data**: groundwater wells surrounding the landfill were sampled and laboratory analyses undertaken for contaminants of interest.
- **Surface water monitoring data**: surface water sites and leachate sites were sampled and laboratory analyses undertaken for contaminants of interest.
- **Air quality monitoring data:** An air quality monitoring program was undertaken.
- **Sub-surface temperature monitoring data**: sub-surface temperature monitoring data was collected at standpipes with the landfill.

2 **Conceptual Site Model**: the CSM developed (URS, 2016a) was used to identify the release and transport mechanisms and pathways for contaminants to move in the environment, contaminants of interest, and the receptors potentially affected by contamination generated by sub-surface hotspots (including people and ecological systems).

3 **Assess Risk to Water and Air**: A qualitative assessment of risk to including assessment of likelihood, consequence and impact and categorisation of the risks.

3.3 Environmental investigation criteria

3.3.1 Surface water and groundwater

The beneficial uses for groundwater and surface water are consistent with those set out for the Darwin Harbour Water Control District under the *Water Act 1992:*

- Agriculture
- Environment
- Cultural
- Rural stock and domestic.

The objectives for these beneficial uses are the triggers identified in Attachment 3 '*Surface Water Monitoring Program and Trigger Values*' of EPL188-03, which are largely drawn from the upper estuary systems water quality objectives specified in Tables 8 and 9 of '*Water Quality Objectives for the Darwin Harbour Region Background Document'* (Northern Territory Government, 2010; the 'Background Document').

Where an objective was not provided in EPL188-03 for a particular chemical or are physico-chemical stressor, values were sought from marine water 90% level of species protection (LOSP) the default guideline values (DGV) specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). This approach is consistent with EPL188-03. There is no nitrate DGV, therefore, the Canadian Council of Ministers of the Environment (CCME) marine ecosystems long term exposure value was adopted for nitrate.

For beneficial uses relevant to human or stock health (e.g., cultural activities, water supply for stock and domestic use), objectives have been drawn from National Health and Medical Research Council (NHMRC) guidelines, including the Australian Drinking Water Guidelines (ADWG) (NHMRC 2011). Table 9 of the Background Document contains biological and microbiological objective for human health, but these parameters are not measured on the site, and have little relevance to assessing impacts due to hotspots.

For the agricultural use, irrigation, the Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) Long Term Irrigation objective were adopted. The Long Term objectives were selected over the Short Term objectives due to their being more conservative.

Water quality objectives for per- and polyfluoroalkyl substances (PFAS) were drawn from the Health Based Guidance Values for PFAS (NHMRC, 2019) for human health objectives. Adopted water quality objectives and their sources are listed in Table 3.1. The same objectives were adopted for groundwater as surface water.

Table 3.1 Adopted water quality objectives

	Marine environment: EPL188-03			Marine environment: other	Agriculture	Domestic & stock water, cultural uses			
Analyte	Darwin Harbour Back ground Document	ANZG (2018) Marine water 90% LOSP)	NEMP 2.0 2020 Marine Water 90% LOSP)	CCME Marine Long Term Exposure	ANZECC Long Term Irrigation	ADWG (PCR/ Aesthetic)	NEMP 2.0 2020 (PCR/ Aesthetic)	ADWG Drinking Water	NEMP 2.0 2020 Drinking Water
Dissolved Oxygen (%)	80-100*								
Total Phosphorus as P (mg/L)	0.03								
Ammonia as NH_3 (mg/L)[#]	0.024								
Nitrate (as NO_3^-) (mg/L)				45		500		50	
Nitrite (as NO_2^-) (mg/L)						30		3	
Nitrogen (Total) (mg/L)	0.3				5				
Benzene (µg/L)		900						1	
pH	6.5-8.0								
Cadmium		0.0014			0.1	0.02		0.002	
Chromium (VI)		0.02							
Chromium (III+VI)		0.02							
Chromium (III)		0.02							
Copper		0.003			0.2	20		2	
Lead		0.0066			2	0.1		0.01	
Nickel		0.2			0.2	0.2		0.02	

	Marine environment: EPL188-03			Marine environment: other	Agriculture	Domestic & stock water, cultural uses			
Naphthalene (µg/L)	90								
Perfluoro-hexane sulfonate (PFHxS) (µg/L)							2		0.07
Perfluoro-octane sulfonic acid (PFOS) (µg/L)			2				2		0.07
Perfluoro-octanoic acid (PFOA) (µg/L)			632				10		0.56

*Approximately equivalent to 7.36–9.2 mg/L at 20°C.

[#] Converted from 0.02 mg/L, which is for 'Ammonia as N', as 'Ammonia as NH_3' was reported.

3.3.2 Air quality

The following legislation and guidelines provide the relevant criteria for assessment of potential impacts to air quality:

- NTEPA Guideline for Reporting on Environmental Monitoring, 2016
- *National Environment Protection (Ambient Air Quality) Measure* (NEPM [AAQ])
- *National Environment Protection (Air Toxics) Measure* Monitoring Investigation Levels (MILs)
- *Guideline for assessing and minimising air pollution in Victoria"* (the Air Pollution Guideline), Victorian Environment Protection Authority (EPA Vic) Publication 1961

The NTEPA reporting and monitoring guideline references the NEPM (AAQ) and NEPM (Air Toxics) as the documents for air quality reference criteria. In addition to these publications, the NTEPA also references the *National Environment Protection (National Pollutant Inventory) Measure 2011* as a criteria document for air quality.

The NEPM AAQ does not contain 24 hour air quality criteria for benzene or ethylbenzene, therefore WSP has also incorporated the EPA Vic Air Pollution Guideline to incorporate 24 hour criteria for benzene and ethylbenzene.

3.3.2.1 NEPM (AAQ)

The NEPM (AAQ) includes environmental quality objectives (EQOs) for particles (as PM_{10} and $PM_{2.5}$) that apply to air quality within a region or sub-region considered to be representative of exposure of the general population. These objectives have been adopted for the purposes of comparison with results from $PM_{2.5}$ monitoring locations.

3.3.2.2 NEPM (air toxics)

The aim of the Air Toxics NEPM is to gain a greater understanding of the levels of air toxics at specific locations where elevated concentrations are likely to occur and where the potential for significant human exposure exists. The Air Toxics NEPM establishes monitoring investigation levels (MILs) for benzene, toluene, and xylene isomers. The MILs were used purposes of comparison with results from the air toxics monitored at the boundary locations.

3.3.2.3 Guideline for Assessing and Minimising Air Pollution in Victoria

The air pollution assessment criteria (APAC) in the Air Pollution Guideline are concentrations of air pollutants that provide a benchmark to understand potential risks. They are risk-based concentrations that help identify when or if an activity is likely to pose an unacceptable risk to human health and the environment.

3.3.3 Air quality criteria

Table 3.2 summarises the air quality criteria adopted for this report.

Table 3.2 Adopted air quality criteria

Contaminant	Units	Criteria	Averaging period	Reference
$PM_{2.5}$	µg/m^3	25	24 hour	NEPM (AAQ)
Benzene	µg/m^3	29	24 hour	Air Pollution Guideline (Vic)
Ethylbenzene	µg/m^3	21712	24 hour	Air Pollution Guideline (Vic)
Formaldehyde	ppb	40	24 hour	NEPM (Air Toxics)
Toluene	ppb	1000	24 hour	NEPM (Air Toxics)
Xylenes	ppb	250	24 hour	NEPM (Air Toxics)

4 Water quality monitoring data review

4.1 Existing water quality monitoring data review

Groundwater, surface water and leachate water quality monitoring data collected by EcOz Environmental Consultants (EcOz) between January 2018 and March 2020 and by Cardno (NT) Pty Ltd (Cardno) between April 2020 and August 2022 was reviewed ('the review period'). EcOz and Cardno report that the monitoring was undertaken at the SBWMF as per the URS (2016a) Water Monitoring Plan and the EcOz Environmental Management Plan (EcOz, 2020b). The information discussed in the following sections is drawn from reports by EcOz (EcOz 2020a), Cardno (2022), and URS (2016b).

4.2 Monitoring network

The network of groundwater and leachate monitoring locations at SBWMF includes ten leachate bores, 43 groundwater bores, and nine surface water and stormwater sampling sites. A subset of groundwater monitoring bores and surface water sites were selected for the monitoring data review. These hotspot monitoring locations were selected based on their proximity to the sub-surface hotspots: the groundwater bores listed in Table 4.1 are positioned north, east, south and west of the area where have been identified, and the stormwater and surface water sampling sites listed in Table 4.2 are located downgradient. Leachate bores were not included in the assessment.

4.2.1 Groundwater locations

GW4-30 is a deep bore and is known to contain water throughout the year. It is located close to the swamp northeast of the SBWMF and is often artesian throughout the wet season, and the SWL only drops to a maximum of 3.0 mbgl in the dry season. In addition, GW 5-12 and GW 7-12 also contain groundwater throughout the dry season. The availability of water for sampling at a number of groundwater and surface water sites is dependent on rainfall. Groundwater at SBWMF is recharged via direct infiltration of rainfall and/or runoff making groundwater levels in the shallow aquifer highly reactive to rainfall (Cardno (NT) Pty Ltd, 2022).

Table 4.1 Groundwater bores and construction details

Bore	Easting	Northing	Position relative to hotspot	PVC elevation (m AHD)	Ground elevation (m AHD)	Screened interval (m bgl)	Screened interval lithology
GW14-3	709013	8630423	East	6.73	6.09	1.5-3	Siltstone
GW14-12	709013	8630423		6.64	6.08	9-12	Siltstone
GW4-3	709775	8630634	North	5.49	4.88	1.5-3	Siltstone
GW4-12	709776	8630633		5.44	5.36	9-12	Siltstone
GW4-30	709777	8630631		5.20	5.33	15-21	Gravelly sand, Sandstone
GW5-3	709880	8630224	West	5.41	4.7	1.5-3	Siltstone
GW5-12	709880	8630226		5.33	4.7	9-12	Siltstone, Gravelly Clay
GW7-3	709900	8629992	South-west	5.33	4.33	1.5-3	Siltstone
GW7-12	709900	8629994		5.03	4.33	9-12	Siltstone, Sandy Silt

4.2.2 Surface water locations

Surface water flows in stormwater drains across the site during and immediately after rainfall although the surface water catchment at SW12 holds water for longer periods. The surface water site SW12 is a sediment dam that holds water throughout the wet season and in the dry season (i.e., is usually only dry from June to September). The surface water sites STG1&2 only contain water immediately after heavy rainfall at the peak of the wet season (i.e., January and February).

Table 4.2 Storm water and surface water monitoring sites

Site ID	Easting (m)	Northing (m)	Position relative to hotspot	Location	Source
SWSTG1&2 (Formerly STG 1&2)	709448	8629979	South	Surface drain between Stage 1 and Stage 2	Receives surface water runoff from central SBWMF areas
SW12	709035	8630495	East (downgradient)	Catchment dam at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells

4.3 Monitoring results

For the selected groundwater and surface water monitoring locations, water quality results from January 2018 to August 2022 (the 'reviewed period') were provided to WSP by the City of Darwin. The data supplied to WSP is in Appendix C, with exceedances of adopted objectives indicated. Selected analytical results have been graphed and presented as figures in Appendix C.

4.3.1 Groundwater level monitoring results

Depth to groundwater measurements collected from the selected wells between January 2018 and August 2022, supplied by City of Darwin were assessed. There is a seasonal fluctuation in groundwater levels in each of the selected wells. The fluctuation ranges from up to 1.5 m variation between wet and dry seasons in GW14-3, to 10 m variation between seasons in GW4-12. Figure C-1.1 of Appendix C shows the relationship between rainfall and cumulative departure from mean (CDM) rainfall. CDM is used to evaluate the temporal correlation of rainfall with surface water or ground water levels. Figure C-1.2 to Figure C-1.5 of Appendix C show the relationship between CDM rainfall and groundwater levels in each of the selected wells.

4.3.2 Groundwater chemistry monitoring results

The following summarises where COI were detected at the selected groundwater monitoring locations.

Metals:

Metals that are required by EPL188-03 for site-wide groundwater monitoring and which may be useful indicators of the impacts of sub-surface hotspots are arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc.

The 2016-2020 water quality review report (EcoOz 2020) noted median concentrations of cadmium, manganese, copper, nickel, lead and zinc above the ANZECC (2000) guidelines, which were the adopted objectives in that report, in several bores on the site including some of the hotspot monitoring locations, as follows:

- Manganese: GW7-3, GW7-12, GW14-12.
- Copper: GW14-3, GW14-12, GW5-3 (marginally), GW7-3.
- Zinc: GW4-3, GW14-3, GW14-12, GW5-3, GW5-12, GW7-3, GW7-12.)

Data for copper, lead and nickel concentrations were available for the selected wells over the date range 2018 to 2022. Concentrations and trends in concentrations of these three metals are summarised below. Generally, only wells GW4-30, GW5-12, GW-7-3, and GW7-12 have been sampled since November 2021.

Copper (see Figure C-1.6 of Appendix C)

Copper concentrations have generally decreased in each of the eight selected wells over the period March 2020 to August 2021 and have been in the range <0.001 mg/L (the limit of reporting; LOR) to 0.005 mg/L since October 2020. Values above the LOR exceed the EPL188-03 value for ANZG (2018) marine water 90% LOSP, the most conservative, of 0.003 mg/L. The ANZECC objectives for irrigation (0.2 mg/L) and NHMRC (2011) primary contact recreation (2 mg/L) have not been exceeded in the reviewed period.

Only GW4-30 (<0.001 mg/L), GW5-12 (0.002 mg/L), GW-7-3 (0.003 mg/L), and GW7-12 (<0.001 mg/L) were sampled since November 2021. Copper concentrations in these wells appear to have remained steady and remain in a similar magnitude to the 90% LOSP objective (EPL188-03 ANZG 2018). That is, increases in copper concentrations have not been detected subsequent to the detection of the hotspots.

Lead (see Figure C-1.7 of Appendix C)

Concentrations of lead in the selected wells have been at or up to two times the LOR over the period 2018 to August 2022, that is, in the range <0.001 mg/L to 0.002 mg/L. These concentrations do not exceed the adopted objectives for lead, the most conservative of which is the 90% LOSP value of 0.007 mg/L (EPL188-03 ANZG 2018), which is applied to contaminants that bioaccumulate. Only GW4-30, GW5-12, GW7-3, and GW7-12 have been analysed for lead since November 2021, and the concentrations were in the range <0.001 mg/L to 0.001 mg/L. Therefore, increases in lead concentrations have not been detected subsequent to the detection of the hotspots.

Nickel (see Figure C-1.8 of Appendix C)

Nickel concentrations in most of the selected wells have been steady over the reviewed period. The objectives for irrigation (0.2 mg/L and 2 mg/L for long-term and short-term respectively) and NHMRC (2011) primary contact recreation (0.2 mg/L) have not been exceeded in the selected wells during the reviewed period. Nickel concentrations in wells have been below the most stringent adopted objective of 0.2 mg/L for 90% LOSP (EPL188-03 ANZG 2018).

Nickel concentrations in GW7-3 have fluctuated by up to five-fold, between 0.005 mg/L (and 0.025 mg/L (below the 90% LOSP objective), over the period assessed. In GW7-12, concentrations have fluctuated approximately two-fold, between 0.005 mg/L and 0.012 mg/L (below the 90% LOSP objective).

Only GW4-30, GW5-12, GW7-3, and GW7-12 have been analysed for nickel since November 2021, and no exceedance of the adopted objectives were reported. That is, increases in nickel concentrations have not been detected subsequent to the detection of the hotspots.

Organic species

The COIs that are included in EPL188-03 site-wide groundwater monitoring that may be useful indicators of impacts of sub-surface hotspots include: phenols, monocyclic aromatic hydrocarbons (MAH, including benzene, toluene, ethylbenzene, xylene BTEX) polyaromatic hydrocarbons (PAH: naphthalene and benzopyrene), benzo(a)pyrene, total recoverable hydrocarbons (TRH: C_6–C_9 hydrocarbons, C_{10}–C_{36} hydrocarbons, sum of C_{10}–C_{40}), polychlorinated biphenyls, (PCB) chlorinated hydrocarbons and C_1–C_4 gases in water. Of these, data for total phenols, total PAH, total PCB, BTEX, TRH, and naphthalene were available.

Naphthalene, BTEX, PAH, PCBs and total phenols were below the LOR at the selected monitoring wells over the reviewed period. TRH was detected in GW4-30 and GW5-12 at a concentration of 0.1 mg/L in October 2020; this is equivalent to the LOR. Only wells GW5-12, GW7-3, GW7-12, GW14-3, and GW14-12 were sampled in 2022, but there were no increases in organics concentrations reported subsequent to the detection of the hotspots.

PFAS

PFAS results are plotted in Figure C-1.9 of Appendix C. PFOS, PFOA, and PFHxS were below the LOR in GW4-3, GW5-12, GW14-12, and GW4-30. The LOR for the analyses undertaken was <0.01 µg/L for each of these PFAS species.

In wells, GW5-3, GW7-3, GW7-12, and GW14-3, PFOS, PFOA, and PFHxS were reported above the LOR as follows:

- PFOA concentrations were below relevant objectives in each well.
- PFOS concentrations were below the EPL188-03 environmental objective and the primary contact recreation/cultural objective (both being 2 µg/L) in each sample analysed. PFOS concentrations in GW7-3 were above the NHMRC (2019) objective of 0.07 µg/L for each sample analysed, as was the sample from GW7-12 in November 2021.
- PFHxS concentrations were above the NHMRC (2019) objective of 0.07 µg/L in each GW7-3 sample analysed, and in three of four GW14-3 samples analysed. No environmental objectives were adopted for PFHxS.
- Concentrations of PFAS in GW5-3, GW7-3, GW7-12, and GW14-3 fluctuated, with the three generally species mirroring each other. Concentrations in the November 2021 sample were higher than the May/August 2022 sample.

There were no increases in PFAS concentrations reported subsequent to the detection of the hotspots.

Inorganics

Inorganic parameters that are included in EPL188-03 groundwater monitoring include major ions (carbonate, bicarbonate, sulfate), nutrients (e.g., ammonia, nitrate as NO_3, total phosphorous) and total dissolved solids as well as physico-chemical parameters such as pH, dissolved oxygen (DO), and oxidation-reduction potential (ORP or 'redox'). These parameters and their ratios are indicators of processes that are relevant to groundwater and leachate associated with landfills, such as:

- Leachate infiltration to groundwater and vice versa (ratio of potassium, ammonium and nitrate ions to calcium, sodium and magnesium ions).
- Freshwater recharge or infiltration (alkalinity, concentration of chloride).
- Landfill waste decomposition (ORP, pH, DO, concentrations of nitrate and sulphate).

These process and their indicators are interrelated, thus, changes in concentrations of these parameters are difficult to interpret. Notwithstanding, selected inorganic parameters were assessed for trends to understand impacts, if any, of the subsurface hotspots. Data were available for GW4-30, GW5-12, GW7-3, GW7-12, GW14-3, and GW14-12.

Nitrate as NO_3 (see Figure C-1.10 of Appendix C)

There were no exceedances of the primary contact recreation objective of 500 mg/L in the selected wells, although the ADWG health guideline of 50 mg/L was exceeded in GW7-3 in February 2019. This concentration also exceeded the CCME objective for nitrate exposure of marine ecosystems (45 mg/L). Seasonal fluctuations were notable in GW5-3, GW14-3, and GW7-3. Overall, except for GW14-12, no increasing trends between November 2021 and May/August 2022 were evident. In GW14-12 in May 2022, nitrate concentration was 3.6 mg/L compared to the November 2021 result of 0.64 mg/L and the previous maximum of 1.07 mg/L in July 2018. Nitrate in this well remains below the CCME objective by a factor of approximately twelve.

Alkalinity (see Figure C-1.11 of Appendix C)

Total alkalinity (as calcium carbonate) is calculated by the laboratory as a function of the ratio of carbonate and bicarbonate ions. Total alkalinity is relatively stable in most of the selected wells. That is, the concentration in each of the wells maintains a characteristic baseline concentration. For example, GW4-3 is typically around the LOR (<20 mg/L) and GW7-12 is typically around 150 g/L over the reviewed period.

GW4-30 and GW4-12 have seasonal fluctuations of up to approximately 20-fold (GW4-30: ranging from <20 mg/L to 440 mg/L) and approximately 30-fold (GW4-12; April 2021 is the most recent data point). Notwithstanding, no overall trend in alkalinity over the reviewed period was detected in these two wells.

pH (see Figure C-1.12 of Appendix C)

pH in GW4-3, GW4-30, GW7-3, GW14-3, and GW14-12 have typically been acidic (below the EPL188-03 objective lower limit of 6 units). GW4-12 has typically been alkaline (above the EPL188-03 objective upper limit of 8.5 units). The other wells have generally been within the objective range, i.e., approximately neutral.

The seasonal fluctuations observed in alkalinity in GW4-12 and GW4-30 is reflected in the pH of the groundwater in these two wells. Overall, across the selected wells, a slight upwards trend in pH, towards a neutral pH, is indicated between November 2021 and May/August 2022.

DO% (see Figure C-1.13 of Appendix C)

Dissolved oxygen has been variable in each of the selected groundwater wells but has been consistently below the lower limit of the EPL188-03 objective range of 80% in the wells. Prior to November 2021, there have been no trends in common in the wells. However, for the six wells that have a DO concentration reported for November 2021, that concentration is one of the maximum values recorded except in GW7-3, in which the August 2021 measurement was higher. The following DO measurement, from May or August 2022, is in a more typical range for each particular well. Therefore, there is potentially a trend in DO concentration subsequent to the detection of the hotspots.

4.3.3 Surface water monitoring results

The following summarises COI concentrations, trends if any, and exceedances of objectives, if any, for the selected surface water monitoring sites, SWSTG1&2 and SW12 over the reviewed period. As noted in Section 4.2, the surface water sites STG1&2 only contain water immediately after heavy rainfall at the peak of the wet season (i.e., January and February), therefore the dataset for STG1&2 is limited for some analytes between 2018 and 2022.

Metals:

Metals that are required by EPL188-03 for site-wide surface water monitoring are boron, cadmium, chromium, copper, lead, nickel, and zinc.

Data for copper, lead and nickel concentrations were available for the SWSTG1&2 and SW12 over the reviewed period from early 2018 to mid-2022. There were only four data points for SWSTG1&2 for metals. Surface water metals data are summarised below.

Copper (see Figure C-1.14 of Appendix C)

Copper concentrations in SWSTG1&2 have been at approximately the LOR (0.001 mg/L) for the last three sampling rounds, January to April 2022. This concentration is below relevant objectives, including the ANZG (2018) objective (0.003 mg/L). The previous sample, taken in February 2018, was 0.005 mg/L, which exceeds the ANZG (2018) objective and the EPL188-03 value for ANZG (2018) marine water 90% LOSP (0.003 mg/L).

Copper has been analysed in SW12 nine times. The copper concentration has been in the range 0.011 mg/L to 0.003 mg/L for the last four rounds of sampling, between November 2021 and February 2022. These concentrations exceed the objective for the 90% LOSP (EPL188-03 ANZG 2018) but no trend in copper concentrations were detected over the reviewed period. No other objectives were exceeded for copper.

Lead (see Figure C-1.15 of Appendix C)

Lead concentrations in SWSTG1&2 have been reported as below the LOR (<0.001 mg/L) in each sample collected. Lead has been analysed in SW12 nine times. Concentration of lead has been reported as below the LOR (<0.001 mg/L) in each sample except that collected in March 2020 (0.003 mg/L) and November 2021 (0.005 mg/L). These samples are below the 90% LOSP objective of 0.007 mg/L (EPL188-03 ANZG 2018) for bioaccumulating contaminants. No trend in lead concentrations were detected over the reviewed period.

Nickel (see Figure C-1.16 of Appendix C)

Nickel concentrations in SWSTG1&2 and SW12 have been between the LOR (<0.001 mg/L) up to 0.012 mg/L across all samples. Nickel concentration has not exceeded the adopted objectives at this location.

No trend in nickel concentrations were detected over the reviewed period.

Organic species

The COIs that are included in EPL188-03 site-wide groundwater monitoring that may be useful indicators of impacts of sub-surface hotspots include TRH, BTEX, and naphthalene. BTEX, TRH (sum of C_{10}–C_{40}), and naphthalene were available. Some other organic species not included in EPL188-03, for example phenols and total PCB, have been analysed in surface water on a few occasions.

Naphthalene, BTEX, PAH, total PCBs, and total phenols were below the LOR at the selected surface water sites over the reviewed period. TRH was detected in SW12 at a concentration of 0.4 mg/L in June 2021, but results were below the LOR in the most recent two samples, October 2021 and January 2022. There were therefore no increases in organics concentrations reported subsequent to the detection of the hotspots.

PFAS

PFAS have been analysed in the selected surface water locations twice, in January 2021 and January 2022. PFOS, PFOA, and PFHxS were below the LOR in SWSTG1&2 on both occasions. In SW12, concentrations were as follows:

- PFOA concentrations, of 0.22 µ g/L (2021) and 0.42 µ g/L (2022), were below relevant objectives.
- PFOS concentrations, of 0.03 µ g/L (2021) and 0.03 µ g/L (2022) were below relevant objectives.
- PFHxS concentrations were below the most stringent objective (NEMP 2.0, 2020) of 0.07 µg/L, being 0.03 µg/L in 2021 and 0.01 µg/L in 2022.

Two data points are not sufficient to interpret a trend; however, it is noted that the PFOA concentration increased between January 2021 and January 2022, while the PFHxS concentration decreased.

Inorganics

Inorganic parameters that are included in EPL188-03 surface water monitoring include major ions (e.g., sulfate, chloride), nutrients (e.g., total nitrogen, total phosphorous) and total dissolved solids as well as physico-chemical parameters such as pH, DO, and ORP. For many of these parameters, the data set is limited or incomplete. Selected inorganic parameters were assessed for trends to understand impacts, if any, of the subsurface hotspots.

Total nitrogen (see Figure C-1.17 of Appendix C)

Total nitrogen has been analysed in SW12 between June 2021 and May 2022, i.e., prior to and after the detection of the hotspots. Total nitrogen has decreased over that period. Concentrations from June 2021 to December 2021 were in the range 5.2 to 12.1 mg/L, which is above the ANZECC (2000) Long Term irrigation objective (5 mg/L) as well as the EPL188-03 objective (0.3 mg/L). Subsequent to December 2021, concentrations of total nitrogen were below the ANZECC objective but remain above the Darwin Harbour objective.

pH (see Figure C-1.18 of Appendix C)

SWSTG1&2 appeared to reach nadir in pH in January 2022, when the pH was 5.02 units. In February 2022, the pH increased to 8.33 units. At the same time the previous year, the pH was 7.76 (January 2021) and 7.97 (February 2021). Three of the last four measurements collected at SWSTG1&2 were outside of the EPL188-03 objective range of 6.5–8 pH units. However, the pH dataset for SWSTG1&2 is very limited (nine data points over 4 years) and it is not clear whether these changes reflect a long term trend. In SW12, over the year mid-2021 to mid-2022, pH fluctuated over a range 6.01 to 10.96 pH units, but generally between 6 and 8 pH units. The fluctuations appear to be cyclical, and no trend indicating a change in pH since the detection of the hotspots is indicated. Sixteen of 39 pH measurements taken since 2018 at SW12 have been outside of the EPL188-03 objective range of 6.5-8 pH units.

DO % saturation (see Figure C-1.19 of Appendix C)

Dissolved oxygen is generally below the lower limit of the EPL188-03 objective range of 80%. Some of the DO results are above 100% saturation, which could be an artefact of measurement, for example from interference with the DO probe from leachate contaminants, or may be typographical errors. Those anomalies aside, in SW12 DO concentration was at a minimum in January 2022 (21.7%), after reaching 86.6% in November 2021. No DO concentration was reported for December 2021. The last four DO readings taken at SW12 were between 65.8% and 96.5%. DO levels fluctuate in SW12 however, and it is difficult to assess whether changes in DO concentrations are due to seasonal factors such as rainfall, algal growth during warm wet weather, or to the impacts of changing leachate chemistry.

The DO dataset for SWSTG1&2 is very limited, comprising six results over the reviewed period. It is noted that DO concentration was 30.3% in January 2022, and the last three results have been in the range 48.2% to 100%.

4.3.4 Summary of results

4.3.4.1 Groundwater

No increasing trends were identified in groundwater for metals (copper, lead, nickel), organics (naphthalene, BTEX, PAH, PCBs and total phenols), or PFAS (PFOS, PFOA, and PFHxS).

For inorganics, in GW14-12, there is potentially an increasing trend in nitrate, but this is based on a single result, from the May 2022 sample. GW14-12 is east of the sub-surface hotspots. No trends in nitrate concentration were identified in the other selected wells. A slight upwards trend in pH, towards a neutral pH, is indicated between November 2021 and May/August 2022 across the selected wells. No overall trend was identified for alkalinity. There may be a decreasing trend in DO concentration subsequent to the detection of the hotspots.
Exceedances of adopted health and ecosystem protection objectives occurred for metals, both before and after detection of the hotspot in December 2021

4.3.4.2 Surface water

STG1&2 are south of the potential locations of sub-surface hotspots. The results are therefore variable over the reviewed period considered with no apparent trend or change since December 2021. There is therefore no apparent impact on stormwater quality associated with the sub-surface hotspots.

5 Air quality monitoring

WSP Golder was engaged by the CoD to undertake an Ambient Air Quality Monitoring Programme (AAQMP) to assess the potential for environmental harm both onsite, and at the nearby sensitive receptors, as required by item 2) c) ii. of the NTEPA, Authorised Officer Direction Notice dated 19 May 2022. The AAQMP was conducted 5 September 2022 to 9 September 2022.

The results of the AAQMP are provided in the report Ambient Air Quality Monitoring Shoal Bay Waste Management Facility (WSP Golder Ref PS132331-011-R-Rev0, 6 December 2022) (Appendix B).

The Ambient Air Quality parameters assessed were:

- Volatile Organic Compounds (VOCs)
- Reduced sulphur compounds
- $PM_{2.5}$
- Odour.

Samples were collected at 3 locations; upwind, onsite and downwind, and were analysed for a suite of 87 VOC and sulphur compounds. Three compounds were detected above the limit of reporting; 2-butanone, cyclohexane, and freon 12. All other compounds were below the limit of reporting. There are currently no 24-hour ambient air quality objectives within the NEPM (Air Toxics) or the Air Pollution Guideline for the detected compounds.

The results for $PM_{2.5}$ measured on site show the elevated concentrations occur during site operational hours. The $PM_{2.5}$ concentration is significantly lower outside of the site operational hours, suggesting localised $PM_{2.5}$ concentration is strongly influenced by site-based operational activities.

The offsite $PM_{2.5}$ results varying between locations. The results at the downwind location, representing residential receptors, were all below the air quality objective of 25 $\mu g/m^3$. Upwind of the Site follows the same concentration pattern as the Downwind location. The highest $PM_{2.5}$ results at both locations occurred on 6 to 7 September, the second highest result was recorded on 8 to 9 September. All results at the upwind locations were above the air quality objective of 25 $\mu g/m^3$.

The onsite $PM_{2.5}$ results did not follow the same trends as the upwind and downwind locations. The highest concentration measured onsite, was significantly higher than either of the other locations. The onsite results were also more varied than either the upwind or downwind locations, suggesting operational activity at the Site is likely to be a major source contributing factor to the measured on site $PM_{2.5}$ concentrations.

The results of the field and residential odour surveys were conducted each day near the Site boundary and residential areas adjacent to the Site in a down wind direction (wind permitting). No burning odour was detected during any of the boundary odour surveys, the odour assessor undertaking the work noted other odours associated with the Site at varying intensities.

The residential odour surveys resulted in no detections of odour for 90% of the surveys. In four instances over three days, 5, 8, and 9 September, an odour described as ‘burnt’ or ‘smoke’ was detected. In three of the four instances, the odour intensity was ‘1 – very weak’, the other detect had an odour intensity of ‘4 – strong’ and was recorded on 9 September. The wind direction during the residential odour survey on 9 September was recorded as ‘calm’ or blowing from the north and the strong odour detection, was recorded to the south of the Site, along Vanderlin Drive. No odour with characteristics matching ‘burnt’ or ‘smoke’ were detected during the southern boundary survey on the same day.

It is unclear if the odour detection on 9 September; ‘smoke’ with an intensity of ‘4’, was a result of the landfill hotspot, or another source. The odour assessor noted a haze associated with burning vegetation in the surrounding area on that day. Based on WSP Golder’s experience, odour intensities below ‘3 – distinct’, are less likely to cause annoyance and result in complaints. Only one location, during all boundary and residential surveys, was found to have an odour intensity of ‘3’ or above and characteristic matching ‘burnt’ or ‘smoke’.

The results of the AAQMP did therefore not identify off site adverse impacts that could be attributed to sub surface hotspots.

6 Temperature monitoring

An investigation program has been undertaken to understand the vertical and lateral extends of the active hotspot(s), and to assess the current temperature of the active hotspot(s) at the site as described in Section 6.1.

6.1 Hotspot investigation method

Field engineers from WSP attended the site to oversee the Hotspot Drilling Investigation. WSP engaged Terratest Drilling Australia Pty LTD (Terratest) to undertake the drilling works as part of the investigation. The investigation included drilling nominal 110 mm diameter boreholes from the surface of the landform using a track mounted rotary drill rig. The borehole locations were selected in consultation with the driller based on areas of interest, which were accessible for the rig. Some localised earthworks were required to permit drilling in some locations. The localised earthworks were completed by the Landfill Operator.

Drilling locations were selected with an effort to avoid buried shipping containers. An exercise was completed using available historical survey information and aerial photographs to map out where there may be buried shipping containers based on the data available to WSP. This mapping was used when selecting proposed drilling locations.

As-constructed monitoring boreholes locations are shown on Figure 6.1 and Figure 6.6.

Galvanised steel pipe (supplied by Terratest) has been installed in each borehole to enable temperature monitoring comprising threaded galvanised pipe with an end cap placed at the top and bottom of the pipe to reduce potential for surface air ingress and egress of landfill gas (LFG). The pipe surrounds have been backfilled with a cement slurry up to or near the surface level. The drilling was completed using a combination of rotary solid auger (dry method) and wash bore methods.

Boreholes were advanced until refusal, aiming to achieve at least 15 m depth, correlating with the inferred depth of inert waste. The landfill waste is known to contain challenging materials for drilling and was observed to contain mixed waste types including larger fragments of concrete. In all proposed locations refusal of the drill bit occurred on a solid obstruction. Where this occurred at a shallow depth, drilling efforts were moved to a new location typically within 5-10 m of the original hole location, to avoid the obstruction.

Personal gas monitors were used to detect the presence of landfill gas during drilling, predominately carbon monoxide (CO), hydrogen sulphide (H_2S), and methane (CH_4).

Overall, for the two drilling periods from 24 August to 15 September 2022, and 17 to 26 October 2022, a total of **59** temperature monitoring wells were installed at the site. Following installation, the wells were progressively monitored. Note that a period of at least one full day was allowed for ground temperatures in the waste to stabilise prior to monitoring.

Drilling of BH2 encountered a shallow obstruction, drilling recommenced at a nearby location and the new borehole was successfully drilled to 8 m depth and was notated as BH2.1. The unsuccessful borehole BH2 was abandoned and backfilled. It was subsequently decided that only successful boreholes, installed with standpipes for temperature measurements, would take the consecutive borehole number to simplify notation. There were two exceptions at BH26 and BH37 where the drilling location was abandoned due to multiple unsuccessful attempts. BH26 and BH37 were therefore never installed or monitored.

The initial conditions temperature monitoring comprised of monitoring **57** boreholes.

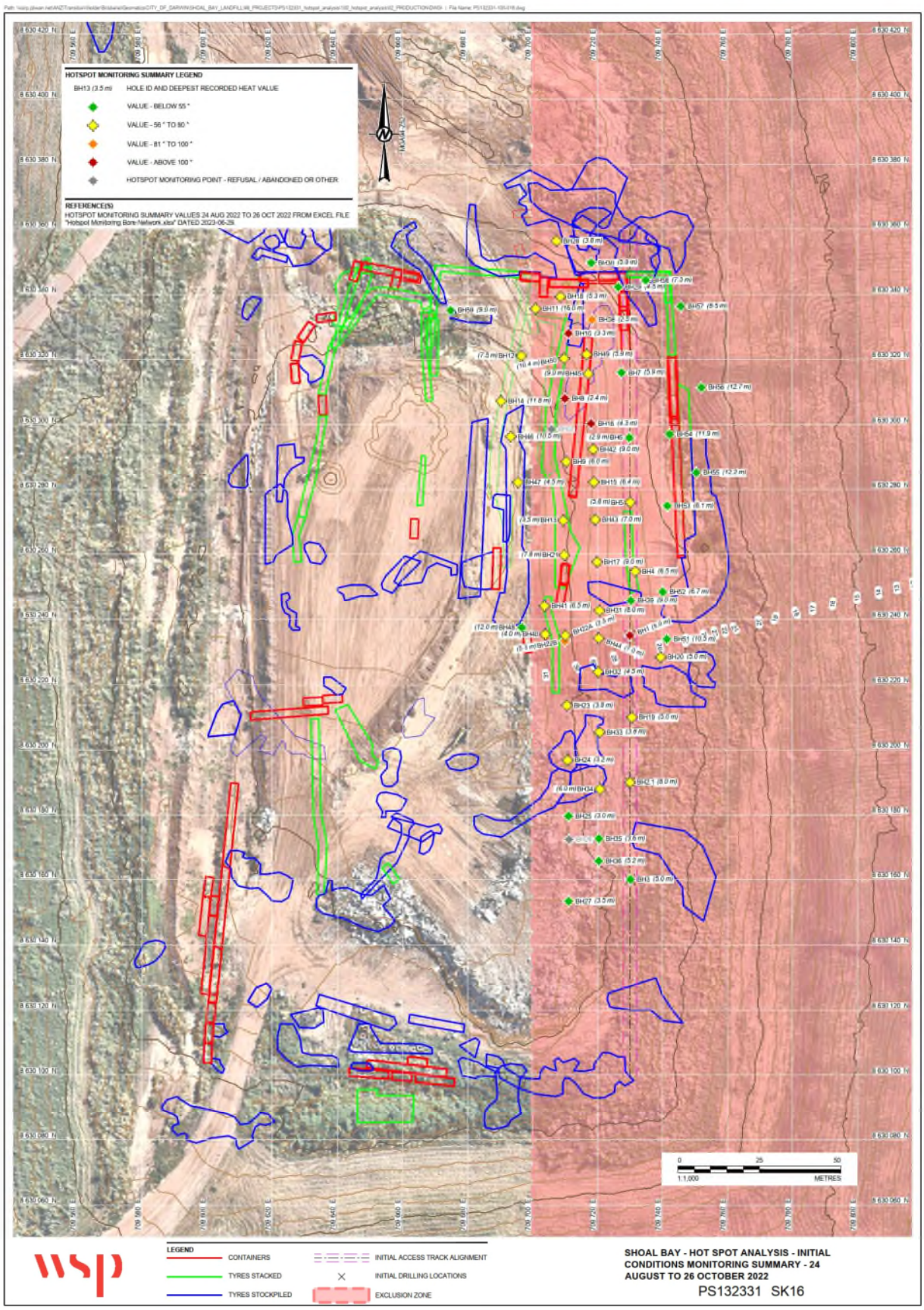


Figure 6.1 Temperature monitoring borehole network – initial conditions

6.2 Interim temperature monitoring results

6.2.1 General

The aim of the drilling investigation is to start to understand the vertical and lateral extends of the active hotspot(s), and to assess the current nature and temperature of the active hotspot(s). The main challenge regarding vertical depth investigation has been the waste types and the resulting difficulty drilling. During the drilling investigations there has been frequent damage to equipment as well as damage to the drilling rig itself. This has resulted in only one borehole reaching the target minimum depth of 15 m, BH11 reached 16 m total depth.

A total of **59** monitoring bores have been drilled during the first two rounds of drilling. A total of **57** monitoring bores were installed. Two bores were drilled but not installed due to collapse and continuous refusal near the surface. Temperature monitoring was conducted during drilling works. The last seven boreholes (BH53–BH59) were not able to be monitored in the final days of the drilling program due to equipment damage. These boreholes were initially monitored when the ongoing temperature monitoring commenced.

Temperature data has been recorded at 1 m intervals across the length of each borehole.

6.2.2 Monitoring results

There are two monitoring data sets. One set of data was taken during drilling works by WSP; this data set is irregular in frequency and was treated as an initial conditions' investigation. The second data set has been compiled weekly by the Landfill Operator; this data set is an ongoing monitoring operation. There was a delay between drilling monitoring and ongoing monitoring of 1.5 months, this time was spent obtaining replacement temperature probes and providing training to the Landfill Operator so that they could continue gathering temperature data on a weekly basis. Data available from the initial and ongoing temperature monitoring has been used to report on temperatures in Stage 2.

Monitoring was carried out (on an irregular basis) by the WSP field staff during drilling between 29 August 2022 and 24 October 2022. A summary of the boreholes exhibiting temperatures exceeding 60°C from the monitoring data is presented in Table 6.1, noting that blank cells indicate that temperatures were below 60°C at the date of monitoring The elevated temperatures were initially found to be between 2 and 3 m below the landfill surface.

Table 6.1 Temperatures exceeding 60°C during initial investigation and ongoing monitoring

Borehole ID	Easting	Northing	Surface RL (m)	Depth of Borehole (m)	Max Temp. (°C) and date	
					Initial conditions investigation	Ongoing monitoring (data since April)
BH01	709729.957	8630235.035	27.14	5	133.4 (01/09/2022)	61.2 (19/06/2023)
BH03	709730.111	8630160.071	27.93	5		63.6 (19/06/2023)
BH04	709731.606	8630254.789	26.34	6.5	75.8 (09/09/2022)	64.9 (19/06/2023)
BH05	709730.089	8630275.99	26.46	5.8	67.5 (09/09/2022)	68.9 (21/04/2023)
BH08	709710	8630308	29.81	2.4	239 (31/08/2022)	

Borehole ID	Easting	Northing	Surface RL (m)	Depth of Borehole (m)	Max Temp. (°C) and date	
					Initial conditions investigation	Ongoing monitoring (data since April)
BH09	709710.4	8630288.6	30.02	6	77.4 (19/10/2022)	61.7 (26/05/2023)
BH10	709711.048	8630328.125	28.38	3.3	107.2 (01/09/2022)	
BH11	709701	8630335.659	27.78	16	70.7 (02/09/2022)	60.8 (12/06/2023)
BH12	709696.569	8630321.11	30.34	7.5	73.6 (11/10/2022)	64.1 (12/06/2023)
BH13	709709.501	8630270.445	30.18	3.5	73.2 (19/10/2022)	61.9 (19/06/2023)
BH14	709690.345	8630307.193	32.468	11.8	69.2 (07/09/2022)	63.3 (12/06/2023)
BH15	709718.875	8630282.234	28.95	6.4	85.1 (12/09/2022)	64.2 (12/06/2023)
BH16	709718.028	8630300.317	28.87	4.3	101.2 (08/09/2022)	68.9 (12/06/2023)
BH17	709718.821	8630282.3602	28.935	9	63.4 (14/09/2022)	75.4 (19/06/2023)
BH18	709708.595	8630339.327	27.373	5.3	71.5 (19/10/2022)	
BH19	709730.606	8630209.995	27.571	5	70.7 (09/09/2022)	
BH20	709739.441	8630228.418	25.936	5	65.4 (10/09/2022)	
BH21	709709.797	8630259.814	20.226	7.8	71.8 (11/09/2022)	90 (12/05/2023)
BH22A	709710.124	8630235.034	30.582	2.5	66.2 (10/09/2022)	
BH22B	709709.911	8630233.351	30.605	5.3	87.5 (19/10/2022)	
BH23	709710.6	8630213.647	30.684	3.8	69.4 (14/09/2022)	
BH24	709710.824	8630196.791	30.787	3.2	68.4 (12/09/2022)	63.6 (19/06/2023)

Borehole ID	Easting	Northing	Surface RL (m)	Depth of Borehole (m)	Max Temp. (°C) and date	
					Initial conditions investigation	Ongoing monitoring (data since April)
BH31	709720.552	8630242.677	28.763	8	71 (13/09/2022)	64.2 (19/06/2023)
BH32	709720.184	8630223.908	28.953	4.5	75.6 (13/09/2022)	64.7 (19/06/2023)
BH33	709720.668	8630205.378	29.221	3.8	74.8 (14/09/2022)	
BH34	709720.765	8630187.854	29.519	6	63.1 (14/09/2022)	61.1 (19/06/2023)
BH38	709718.291	8630332.28	27.27	2.5	80.1 (07/10/2022)	
BH39	709730.248	8630245.742	27.035	9	63.5 (03/10/2022)	62.3 (19/06/2023)
BH40	709703.935	8630235.38	31.441	4	65.6 (06/10/2022)	
BH41	709703.712	8630244.04	31.652	6.5	70 (16/09/2022)	60.6 (19/06/2023)
BH42	709718.669	8630292.383	28.83	9	63.2 (18/10/2022)	66.1 (12/06/2023)
BH43	709719.327	8630270.668	28.687	7	63.6 (18/10/2022)	73.4 (19/06/2023)
BH44	709720.369	8630234.202	28.949	7	66.9 (19/10/2022)	61.5 (21/04/2023)
BH45	709717.183	8630315.672	29.07	9	73.9 (23/10/2022)	67.9 (12/06/2023)
BH46	709693.3	8630296.306	32.447	10.5	62.6 (21/10/2022)	61.7 (12/06/2023)
BH47	709695.57	8630282.152	32.376	4.5	60.8 (23/10/2022)	
BH48	709696.722	8630237.478	32.124	12		65.2 (12/06/2023)
BH49	709716.653	8630321.573	28.703	5.9	65.8 (24/10/2022)	63.3 (12/06/2023)
BH50	709709.753	8630320.327	29.343	10.4	71.5 (21/10/2022)	68.2 (12/06/2023)

Damage occurred to the standpipe of BH22B between drilling and ongoing monitoring, making this borehole no longer accessible – taking the total number of monitoring bores to **56**.

The locations of elevated temperatures can be seen on Figure 6.1, the hotspots initially appear to be in two potentially independent locations, one to the north (in the area of BH8) and one to the south (in the area of BH1). The downward temperature trends of boreholes exceeding 80°C during the initial conditions' investigation listed in Table 6.1 (except for BH22B) are presented in Figure 6.2.

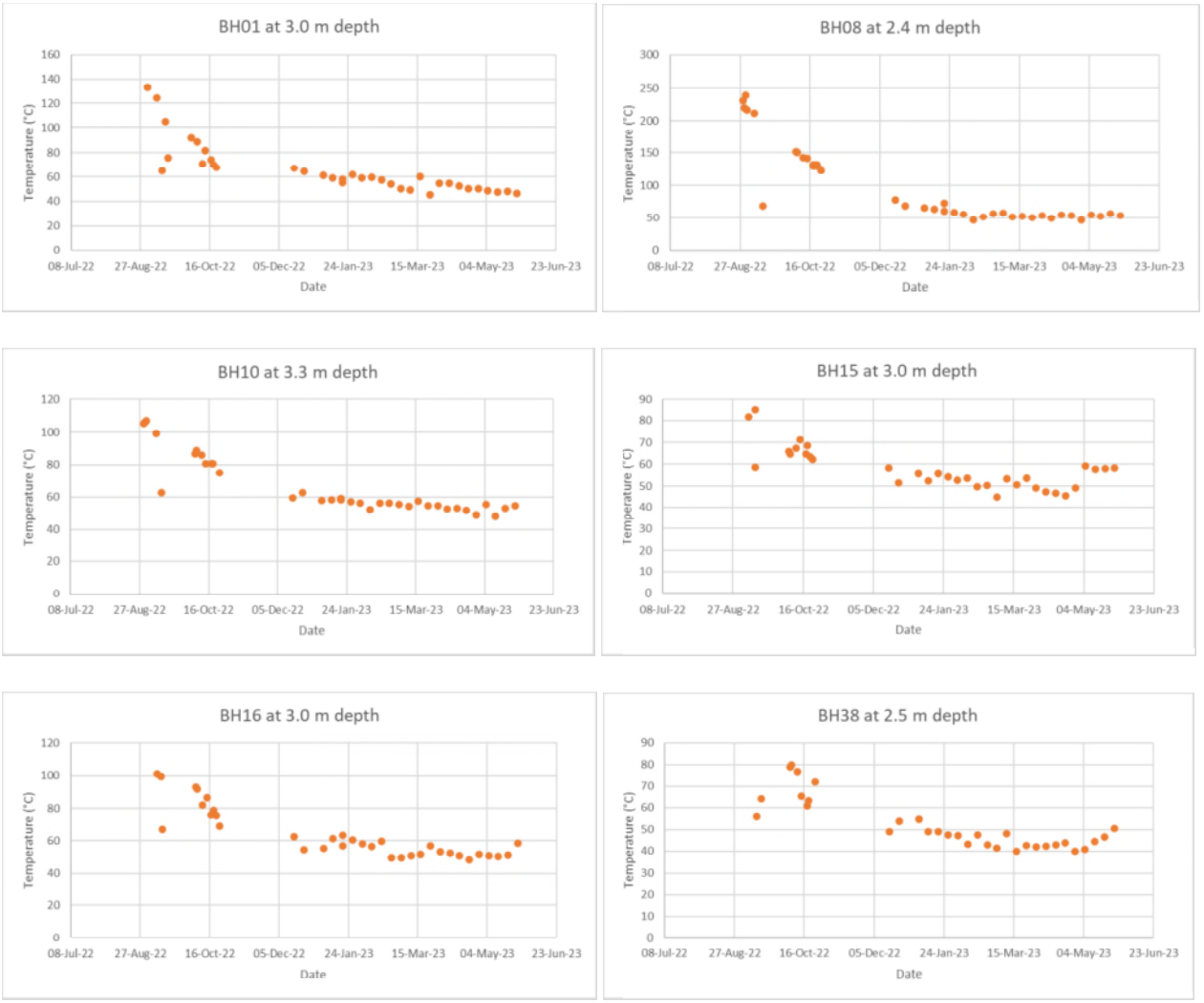


Figure 6.2 Temperature at boreholes BH01, BH08, BH10, BH15, BH16, and BH38

Temperatures dropped to below 60°C in all six locations and remain currently stable in the range of 40–60°C.

There are currently three locations; BH17, BH43 and BH21, where the initial temperatures were between 50 and 60°C but have gradually increased since April 2023. BH17 and BH43 have increased to between 70 and 80°C, while BH21 is currently exceeding 80°C. The increase in temperature is occurring at approximately 7–9 m below the landfill surface, a greater depth than the initial elevated temperatures which occurred between 2 and 3 m below the surface.

The temperature trends for these bores are shown in Figure 6.3.

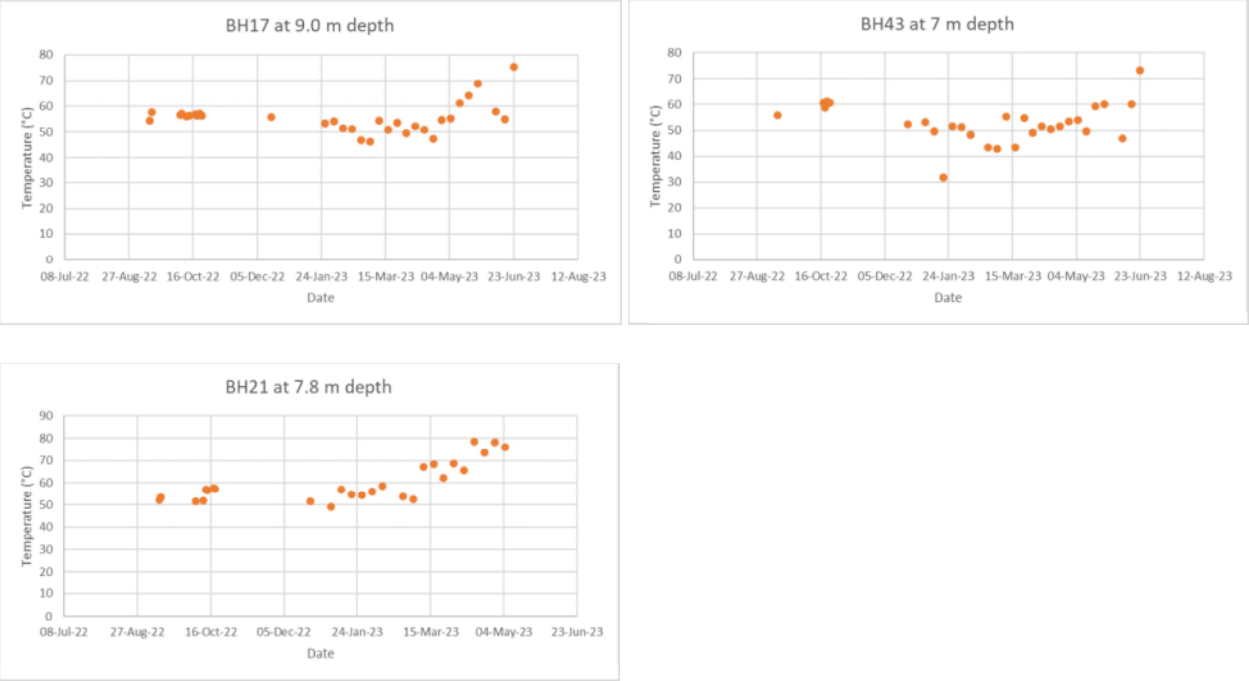


Figure 6.3 Temperature in boreholes BH17, BH43, and BH21

For the remaining 47 boreholes, the ongoing temperatures measured have remained relatively stable, in line with the temperatures measured initially during drilling. These temperatures generally fall between 40 and 60°C. A few trend examples have been selected at random and are provided in Figure 6.4 to demonstrate the boreholes with stable temperatures.

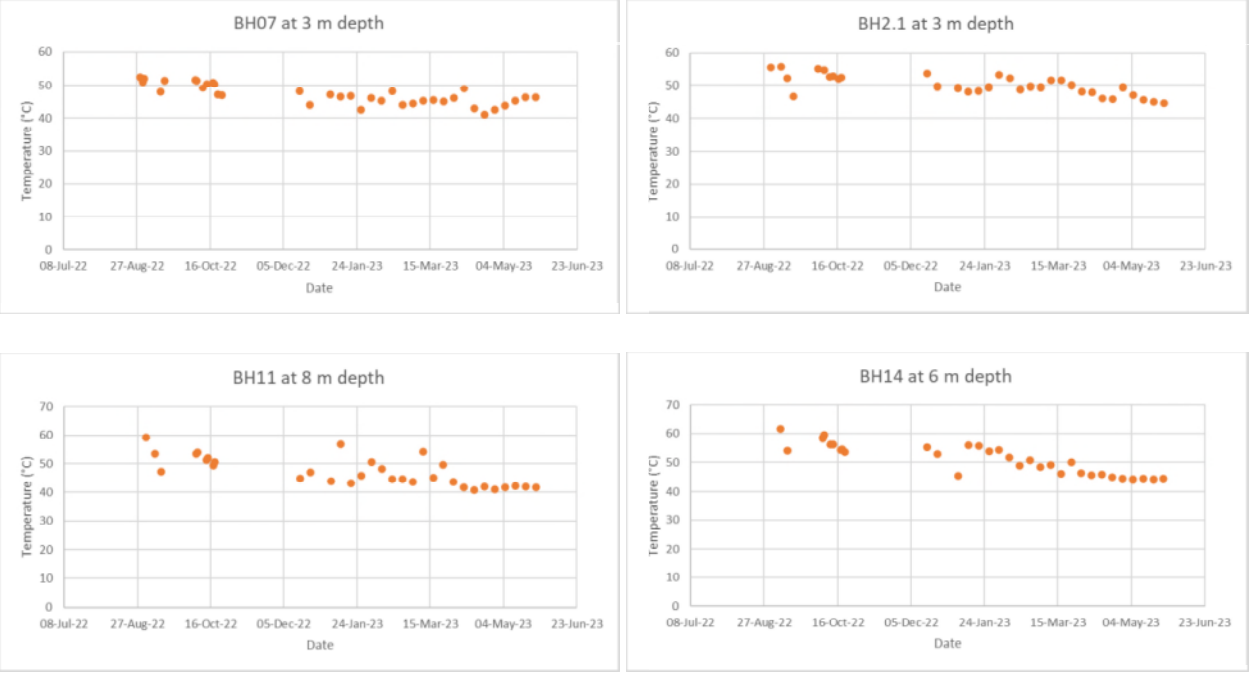
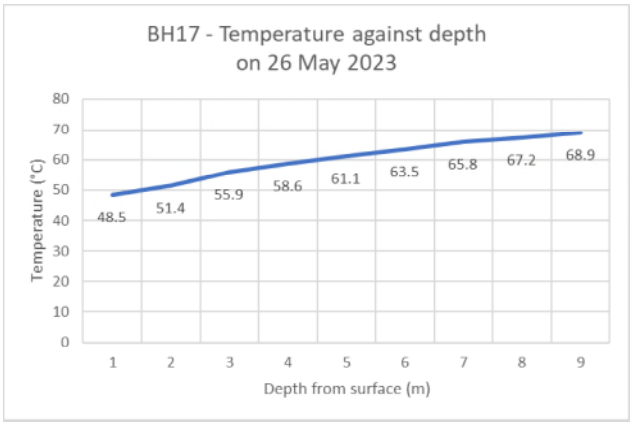
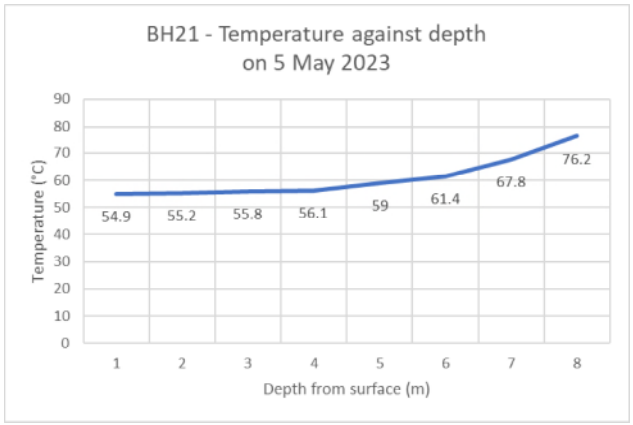


Figure 6.4 Temperature in boreholes BH07, BH2.1, BH11, and BH14

Where elevated temperatures were found in boreholes, temperature tended to increase with increasing depth. Examples of varying temperature with depth are provided in Figure 6.5. In each example shown the maximum depth of the borehole did not correspond to the likely maximum depth of waste deposited (Sections 2.1.1 and 6.1). Some uncertainty therefore exists as to whether higher temperature may be encountered at these locations at greater depths. Similarly for boreholes where temperatures are not currently elevated uncertainty exists as to whether higher temperatures may be present at greater depths than that to which the boreholes could be established.





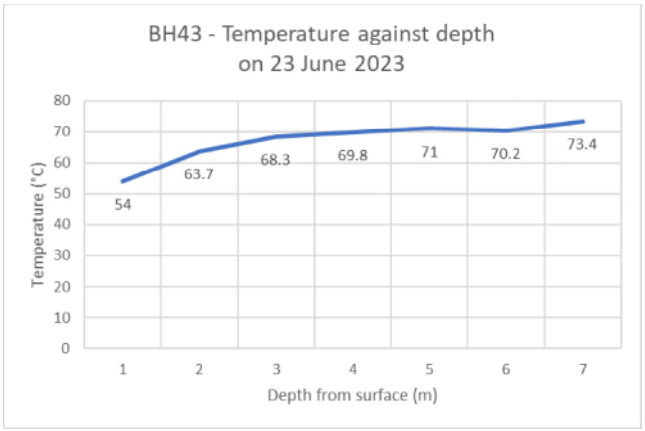


Figure 6.5 Temperature at depths for boreholes BH17, BH21, and BH43

Figure 6.6 shows the current temperatures across the Stage 2 area. The boreholes with temperatures beginning to rise are central, around BH17.

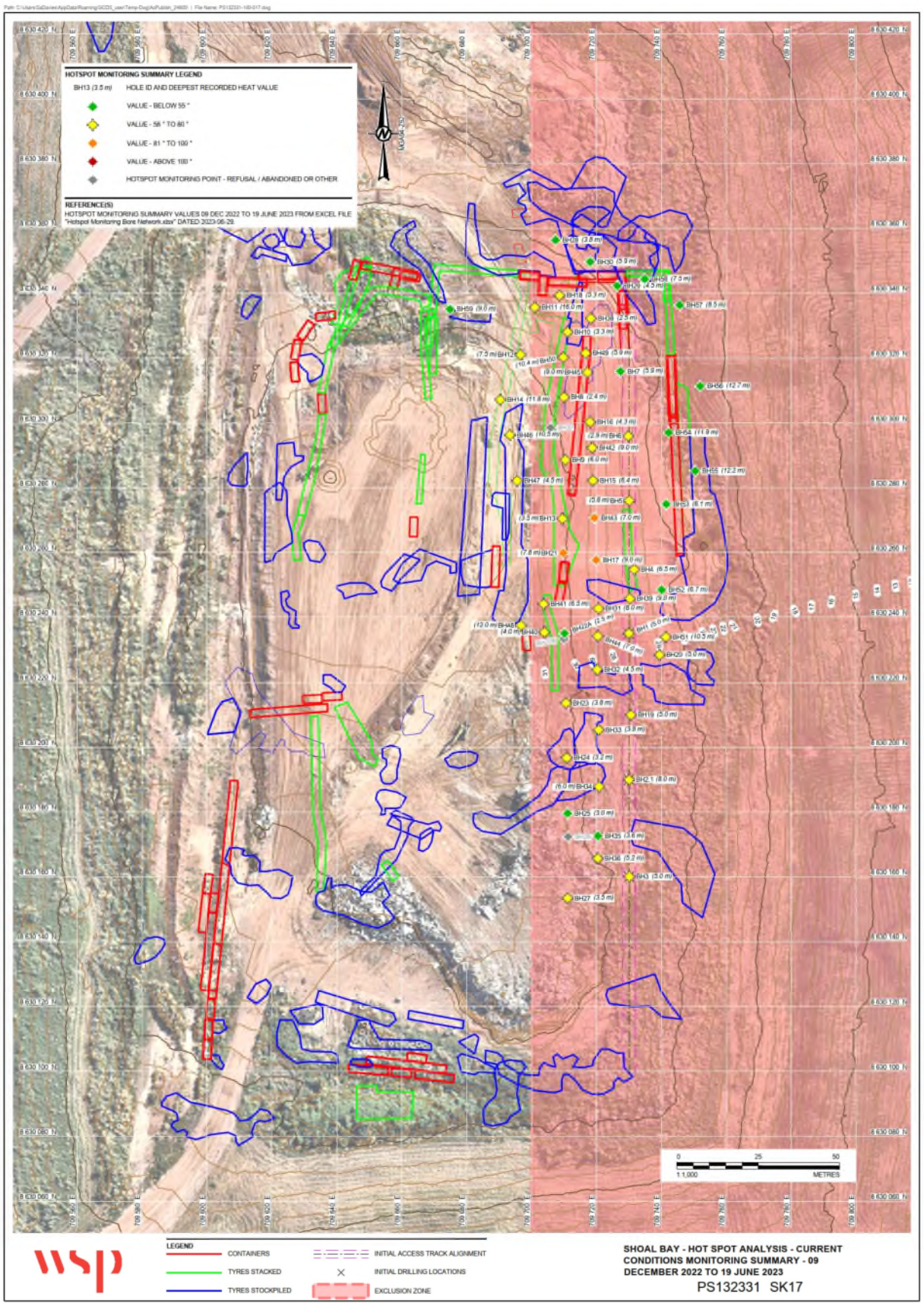


Figure 6.6 Temperature monitoring borehole network – current conditions

6.2.3 *Field observations*

Information on field observations are as provided by the City of Darwin and the landfill operator. WSP has not undertaken independent assessment of landfill conditions other than at the time of establishment of the boreholes and during the air quality monitoring program.

There have been no reports of odour or venting across the Stage 2 surface, by the landfill operator or otherwise. Following high rainfall events, erosion has been repaired to maintain the cover soil thickness and integrity.

The landfill operator has reported one location of venting (upward flow of hot air), this occurred within the standpipe of BH21 in May 2023. It appears that the end cap at the base of the monitoring bore has come loose which has allowed the flow of hot air to travel up the standpipe. Following an inspection of BH21 and surrounds carried out by an Associate Civil Engineer from WSP, due to health and safety risks, monitoring in this bore was recommended to cease.

In June 2023, Veolia completed its own risk assessment of the conditions and considered monitoring of BH21 to be safe. Veolia reported that the temperature at 7 m depth was 110°C. Temperatures at BH21 appear to be exhibiting the signs of an active hotspot.

CoD advise that field observations continue to be recorded by the landfill operator during the weekly temperature monitoring rounds including visual signs (such as subsidence, venting steam or smoke) or odour presence.

6.3 Summary and discussion

6.3.1 *Evidence of hotspot activity*

Based on the monitoring undertaken at the time of borehole establishment and the ongoing monitoring the following bores as shown in Table 6.2 were identified as having elevated temperatures which may indicate active hotspot conditions:

Table 6.2 Summary of bores with elevated temperatures (> 80°C) or increasing temperatures

Borehole	Period of identified elevated temperature	Location	Trend	Current status
BH01	Initial	Central	Declining temperature to stable	Less than 60°C
BH08	Initial	Northern	Declining temperature to stable	Less than 60°C
BH10	Initial	Northern	Declining temperature to stable	Less than 60°C
BH15	Initial	Central	Declining temperature to stable	Less than 60°C
BH16	Initial	Northern	Declining temperature to stable	Less than 60°C
BH17	Ongoing	Central	Increasing temperature	Approximately 75°C
BH21	Ongoing	Central	Increasing temperature	Approximately 90°C
BH22B	Initial	Central	Elevated initial temperature	Decommissioned
BH38	Initial	Northern	Declining temperature to stable	Less than 60°C
BH43	Ongoing	Central	Increasing temperature	Approximately 75°C

Based on the initial monitoring the suspected hotspot locations were identified as being:

- In the northern area of Stage 2 in the vicinity of BH08, BH10, BH16, and BH38.
- In the southern area of Stage 2 in the vicinity of BH01 and BH22B.

The most recent monitoring shows that the temperature in these bores is now below approximately 60°C and therefore does not indicate the likely current presence of a hotspot. Temperatures in other bores in the vicinity of these bores also do not show elevated temperatures.

Based on the most recent monitoring, the suspected active hotspot location was identified as being:

- In the central area of Stage 2 in the vicinity of BH17, BH21, and BH43.

Initial temperatures in these bores were not elevated.

The reason for the decline in temperatures at boreholes initially identified as having elevated temperatures is unknown. Potential reasons for the changes in temperature may be:

- Improvements to landfill capping reducing ingress of air
- Rising groundwater levels during the wet season may have suppressed the hotspots.
- Combustible material in the vicinity of the hotspot has been consumed or exhausted.
- Hotspots remain but are at a depth greater than the boreholes in the monitoring bore network.
- Hotspots are moving with connection at a depth greater than monitoring bore network.

6.3.2 Data gaps and uncertainties

Depth

The method of drilling temperature monitoring boreholes to obtain hotspot data is a useful method of building a picture with regards to temperature at depth. Whilst a network of 57 boreholes has been established, there has been difficulty drilling through the waste types present within the landfill. This has meant that many of the boreholes are shallow with a total depth of less than 5 m. Conditions at depth are uncertain across the entirety of Stage 2. Maximum waste depth is likely to be in the order of 25 to 30 m (Section 2.1.1). As boreholes were generally not able to be installed to the maximum depth of waste disposal the potential exists for undetected elevated temperatures to be present below the base of the installed borehole.

Extent

Drilling boreholes provides point data across the surface, resulting in conditions in areas between bores and areas that are not accessible remaining unknown. The exclusion zone and monitoring network within this zone has been targeted based on site observations. The conditions throughout the rest of Stage 2 remains unknown, noting that CoD has advised that there has not been evidence of venting or smoke in the remaining area of Stage 2.

6.3.3 Next steps

Further drilling should be completed to the west of BH21 to understand the potential extent of elevated temperatures. The intention would be to have at least a row (north south alignment) of bores with temperatures measuring consistently in the range of 40–60°C to better delineate temperatures. This would be carried out iteratively and the extent of the new bores would be dictated by the temperatures observed in initial monitoring. At least four boreholes in a north south alignment would be recommended initially, and if elevated temperatures are observed or signs of active hotspot activity during drilling, the borehole network would be expanded in that direction. This is not limited to north and south.

As well as increasing the monitoring network, ongoing monitoring for at least 12 months is proposed to observe trends throughout the year. An options assessment is proposed to be revisited after 12 months of data is available for review.

7 Qualitative risk assessment

7.1 Methodology

The qualitative risk assessment provides a framework for identifying components of the conceptual site model with the potential to result in environmental impacts and highlights where specific control strategies are required to minimise the likelihood and consequence of identified risks. This section presents a qualitative assessment of the potential risks posed to human health and the environment by sub-surface hotspots at the site. The risk assessment is based on the information available in the reports described in Sections 4 and 5. This risk assessment has been undertaken broadly consistent with the Australian/New Zealand/ISO Standard on Risk Management (AS/NZS ISO 31000:2009). Environmental impacts include impacts to environmental, cultural and socio-economic aspects. Health and safety impacts are not considered in this risk assessment but will be dealt with in the SBWMF Health and Safety Plan.

Where possible it is desirable to put mitigation measures in place that reduce risk to medium or lower. Where risks are ranked as High or Extreme further mitigation controls should be assessed to reduce the risk. Risks evaluated as Medium are considered acceptable subject to monitoring as required. Where further monitoring can assist in resolving uncertainties associated with evaluation of likelihood, the risk ranking should take additional data into account and be re-evaluated accordingly.

Table 7.1 Consequence descriptors

Environmental element	Consequence				
	Negligible	Minor	Moderate	Significant	Severe
Surface water quality	Constituents associated with hotspots in sub-surface waste have no measurable effect on protected environmental values of surface waters.	Constituents associated with hotspots in sub-surface waste have measurable impact but is within range of typical natural variation or does not result in an adverse impact on one or more protected environmental values of surface waters.	Constituents associated with hotspots in sub-surface waste cause temporary and reversible loss of one or more of the protected beneficial use of surface waters.	Constituents associated with hotspots in sub-surface waste cause permanent loss of one or more of the protected environmental values of surface waters.	Constituents associated with hotspots in sub-surface waste cause permanent loss and immediate risk of harm to one or more of the protected beneficial of surface waters.

Environmental element	Consequence				
	Negligible	Minor	Moderate	Significant	Severe
Groundwater	Constituents associated with hotspots in sub-surface waste have no measurable effect on protected environmental values of groundwater.	Release of constituents associated with hotspots in sub-surface waste is measurable but is within range of typical natural variation or does not result in a loss of one or more environmental values of the groundwater.	Release of constituents associated with hotspots in sub-surface waste into the environment causes temporary and reversible loss of one or more environmental values of the groundwater.	Release of constituents associated with hotspots in sub-surface waste causes permanent loss of one or more environmental values of the groundwater on a localised scale.	Release of constituents associated with hotspots in sub-surface waste into the environment causes permanent loss of one or more environmental values of the groundwater across a large geographic area.
Air Quality	No measurable impact on air quality.	Measurable impact on air quality not causing exceedance of applicable air quality standards	Measurable (localised) impacts on air quality causing marginal exceedance of applicable air quality standards	Measurable (widespread) short-term impacts on air quality causing significant exceedances of applicable air quality standards	Measurable (widespread) long- term impacts on air quality causing significant exceedances of applicable air quality standards [resulting in adverse impacts on human health.

7.2 Likelihood

The likelihood of a risk occurring has been assessed using descriptions in Table 7.2. The likelihood evaluation considers current and reasonably foreseeable future risk. It does not include a change in land use.

Table 7.2 Likelihood descriptors

Descriptor	Explanation
Almost certain	The event is expected to occur in most circumstances
Likely	The event will probably occur in most circumstances
Possible	The event could occur
Unlikely	The event could occur but not expected
Rare	The event may occur only in exceptional circumstances

7.3 Consequence

The consequence associated with a risk occurring has been assessed using descriptions in Table 7.1. Consequence descriptors have been developed for each of the major environmental elements.

The level of risk has been assessed by considering the likelihood and consequence in accordance with Table 7.3.

Table 7.3 Risk matrix

Likelihood	Consequence				
	Negligible	Minor	Moderate	Significant	Severe
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	Medium
Rare	Low	Low	Low	Low	Medium

7.4 Risk assessment evaluation

Table 7.4 provides an evaluation of risk to human health and the environment using the methodology outlined in Section 7.1 and the information presented in this review.

Table 7.4 Risk assessment

Beneficial use	Aspect	Potential impact	Pathways for risk (factors influencing risk occurring)	Existing and proposed mitigating factors	Likelihood	Consequence	Risk level	Comments
Groundwater	Migration of constituents associated with hotspots in sub-surface waste from landfill to groundwater	Adverse impact on beneficial uses of groundwater – ecological and human health.	Leaching of constituents into groundwater	Current interim capping would reduce rainfall infiltration and migration of constituents via leaching.	Possible	Moderate	**Medium**	The review of groundwater monitoring data showed that whilst beneficial uses potentially have been impacted this did not appear to be specifically associated with impacts due to sub surface hotspots. Some exceedances of the adopted criteria have been found in downstream wells and there is potentially a trend in pH, nitrate and DO results since detection of the hotspots. The likelihood has therefore been conservatively assessed as "possible". Continued routine monitoring of groundwater should be undertaken.
Surface Water	Migration of constituents associated with hotspots in sub-surface waste from landfill to groundwater and discharge to surface water	Adverse impact on beneficial use of surface water – ecological and human health.	Leaching of constituents into groundwater and discharge to surface water.	Current interim capping would reduce rainfall infiltration and migration of constituents via leaching.	Possible	Moderate	**Medium**	The results are therefore variable over the reviewed period considered with no apparent trend or change since December 2021. There is therefore no apparent impact on stormwater quality associated with the sub-surface hotspots. As some exceedances of the adopted criteria have been found in downstream wells the likelihood has been assessed as "possible". The "moderate" consequence has been assigned as the surface water ecosystem is slightly to moderately disturbed.
	Migration of constituents associated with hotspots in sub-surface waste from landfill to surface waters.	Adverse impact on beneficial use of surface water – ecological and human health.	Migration of constituents associated with sub-surface hotspots via erosion or leaching into surface runoff transported to surface waters.	Management controls are to be implemented to limit erosion of capping soils.	Rare	Moderate	**Low**	The likelihood of "rare" has been assigned due as no apparent impacts associated with landfill hotspots was observed in review of the stormwater monitoring undertaken. The "moderate" consequence has been assigned as the surface water ecosystem is slightly to moderately disturbed.
Air Quality	Active hotspots in sub-surface waste at the landfill emitting pollutants to air adversely impacting on environmental values.	Adverse impact on environmental values of air quality -human health.	Emissions from active hotspots in the sub-surface waste at the landfill.	Waste has interim capping.	Rare	Moderate	**Low**	The likelihood of "rare" has been assigned as the results of the air quality monitoring program found that indicators were below adopted criteria and the distance to sensitive receptors.
		Adverse impact on environmental values of air quality -amenity (odour).	Emissions from active hotspots in the sub-surface waste at the landfill.	Waste has interim capping.	Possible	Moderate	**Medium**	The likelihood of "possible" has been conservatively assigned as the results of the air quality monitoring program found that whilst odours associated with sub-surface hotspots were not positively identified, similar odours were noted. It is therefore not possible to conclude that odours were not due to hotspot activity. The landfill surface should continue to be monitored for indications of the presence of sub surface hotspots such as venting or odours associated with combustion.

8 Conclusions and recommendations

The risks to human health and the environment associated with sub surface hotspots were generally found to be assessed as low or medium risk as follows:

- Air quality – the results of the air quality monitoring program found that indicators were below adopted criteria (low risk), odours associated with sub-surface hotspots were not positively identified, similar odours were noted (medium risk).
- Groundwater – The review of groundwater monitoring data showed that whilst beneficial uses potentially have been impacted this did not appear to be specifically associated with impacts due to sub surface hotspots. Some exceedances of the adopted criteria have been found in downstream wells and there is potentially a trend in pH, nitrate, and DO results since detection of the hotspots (medium risk).
- Surface Water – The results are therefore variable over the reviewed period considered with no apparent trend or change since December 2021. There is therefore no apparent impact on stormwater quality associated with the sub-surface hotspots (medium risk).

Based on the initial monitoring the suspected hotspot locations were identified as being:

- In the northern area of Stage 2 in the vicinity of BH08, BH10, BH16, and BH38.
- In the southern area of Stage 2 in the vicinity of BH01 and BH22B.

The most recent monitoring shows that the temperature in these bores is now below approximately 60°C and therefore does not indicate the likely current presence of a hotspot. Temperatures in other bores in the vicinity of these bores also do not show elevated temperatures.

Based on the most recent monitoring, the suspected active hotspot location was identified as being:

- In the central area of Stage 2 in the vicinity of BH17, BH21, and BH43.

Initial temperatures in these bores were not elevated.

Due to limitations associated with the depth of the temperature monitoring locations there is uncertainty associated with the nature and extent of actual subsurface hotspots within the landfill.

It is recommended that:

- Further drilling be completed to the west of BH21 to understand the potential extent of elevated temperatures.
- Continue monitoring temperature at the existing and future installed boreholes for at least 12 months to observe trends throughout the year. An options assessment is proposed to be revisited after 12 months of data is available for review.
- Continue current groundwater and surface water monitoring programs.
- Continue to implement a program to observe indicators of potential sub surface hotspots by the landfill operator. This should include observations of visual or olfactory evidence of subsurface hotspots (odour, cracking, venting, smoke). Observations should be recorded and consideration given to installation of additional temperature monitoring boreholes if evidence is observed outside the monitoring network.

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10 Limitation Statement Environmental Site Assessment (intrusive)

This Report is provided by WSP Australia Pty Limited (*WSP*) for City of Darwin (*Client*) in response to specific instructions from the Client and in accordance with WSP's proposal dated 9 June 2022 and agreement with the Client dated 10 June 2022 (*Agreement*).

Permitted purpose

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Appendix A

Previous consultants' reports

Quarterly Monitoring Review

Shoal Bay Waste Management Facility Soil and Water Monitoring Program

CW1121900



Prepared for

City of Darwin

24 February 2022

Cardno

now

Stantec

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Our report is based on information made available by the client. The validity and comprehensiveness of supplied information has not been independently verified and, for the purposes of this report, it is assumed that the information provided to Cardno is both complete and accurate. Whilst, to the best of our knowledge, the information contained in this report is accurate at the date of issue, changes may occur to the site conditions, the site context or the applicable planning framework. This report should not be used after any such changes without consulting the provider of the report or a suitably qualified person.

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1 Introduction

Cardno has been commissioned by the City of Darwin (CoD) to undertake groundwater, surface water, leachate, soil and dust deposition monitoring at the Shoal Bay Waste Management Facility (SBWMF) operated by City of Darwin (COD) in accordance with the Site's environmental protection license (EPL) EPL 188 – 03 pursuant to the *NT Waste Management and Pollution Control Act* (WMPC Act).

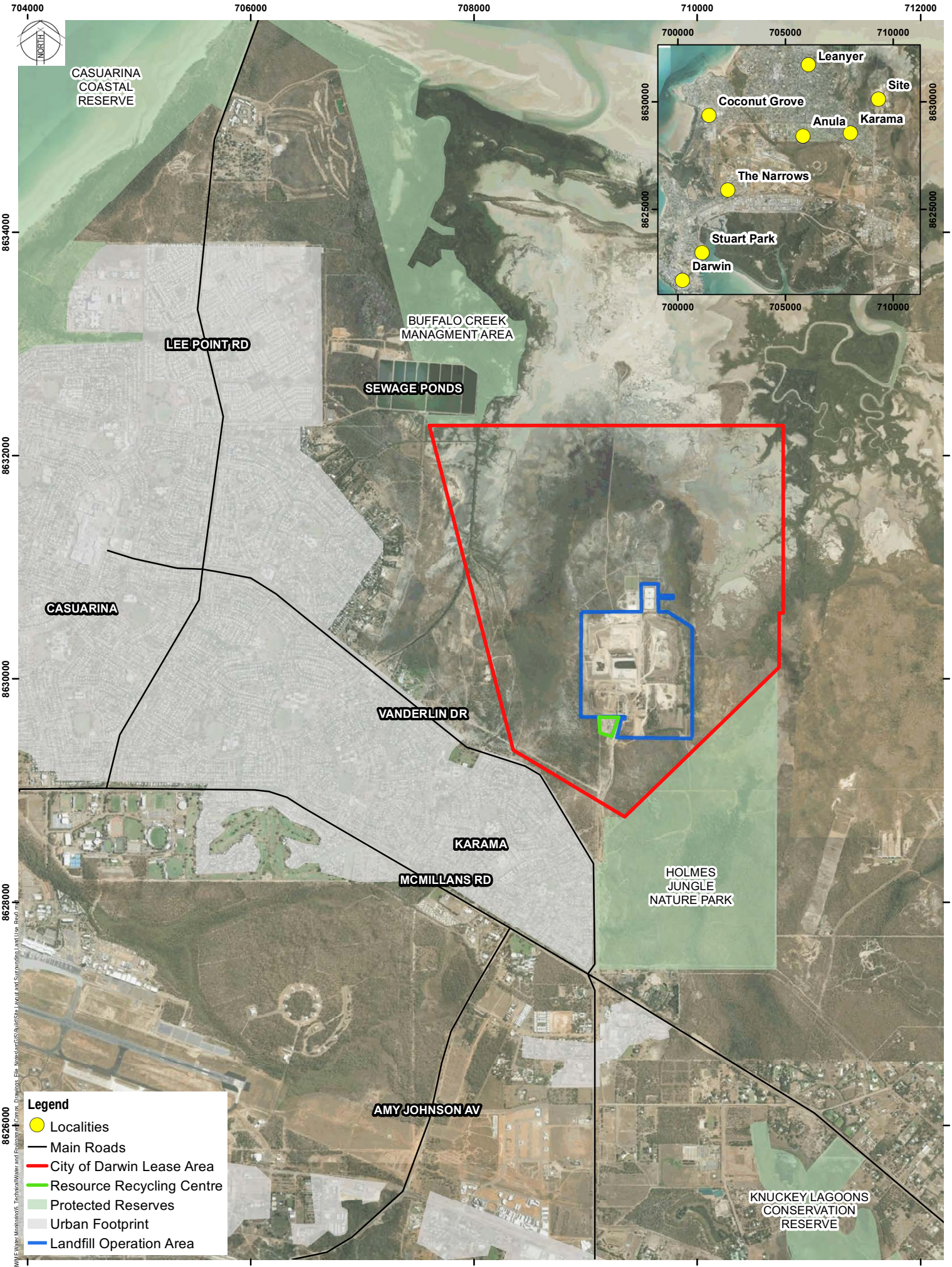
Monitoring activities for the Site are conducted in line with methodologies laid out in the Soil and Water Monitoring Plan (SWMP) (EcOz, 2021a) in order to comply with EPL188-03.



Figure 1-1 Shoal Bay Waste Management Facility

1.1 Site Location

The SBWMF (**Figure1-1**, **Figure 1-2**) is located at Lot 03952 Town of Sanderson Plan S 79/149a, Vanderlin Drive, Holmes, Northern Territory (NT) (herein referred to as 'the Site').



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SITE LOCALITY AND SURROUNDING LAND USE

CITY OF DARWIN

SHOAL BAY WASTE MANAGEMENT FACILITY
ENVIRONMNETAL MANAGEMENT PLAN

FIGURE 1-2

1.2 Purpose and Objectives

The purpose of this Quarterly Review is to provide a summary of all of Cardno's monitoring activities for the period October 2021 to December 2021, including analytical results and assessment against adopted criteria in accordance with the Site's Licence conditions. This review has been prepared in accordance with the requirements of the NT EPA *Guideline for Reporting on Environmental Monitoring* and SWMP to include the following:

- Summary of all surface water, groundwater, leachate, air emissions, depositional and soil monitoring undertaken during the monitoring review period.
- Graphical and tabulated interpretation of all monitoring data for the monitoring period;
- Comparison of results with respect to the adopted quality criteria and/or action levels;
- Discussion of results with respect to long term monitoring data over a three-month period and temporal and spatial trends;
- Assess compliance with regulatory guidelines and standards including notifying the regulator; and
- Provide recommendations for remediation where impacts are identified during monitoring and reporting activities.

Noting analytical data has also been provided separately in Microsoft Excel format month to month.

2 Site Identification

2.1 Site Use

The SBWMF lies within Lot 3952, Town of Sanderson (see **Figure 1-2**) described in EPL 188-03 as a municipal waste resource recovery and disposal site operated by the CoD which services both domestic and commercial customers in the Darwin area. Under the terms and conditions of the lease, the property is designated as a Waste Management Project Area in which CoD is authorised to conduct the following scheduled activities:

- Operating premises for the disposal of waste by burial that service, or are designed to service, the waste disposal requirements of more than 1,000 persons;
- Collecting, transporting, storing, re-cycling, treating or disposing of a listed waste (see **Table 2-1**) on a commercial or fee for service basis, other than in or for the purpose of a sewage treatment plant; and
- Operating premises, other than a sewage treatment plant, associated with collecting, transporting, storing, re-cycling, treating or disposing of a listed waste (see **Table 2-1**) on a commercial or fee for service basis.

Table 2-1 Listed Wastes Authorised to be Handled

Listed Waste	Collection	Transport	Storage	Treatment	Recycling	Disposal
Acidic solutions or acids in solid form	×	×	✓	×	×	×
Animal effluent and residues	×	×	×	×	×	✓
Asbestos	×	×	×	×	×	✓
Clinical and related wastes	×	×	×	×	×	✓
Lead, lead compounds	×	×	✓	×	×	×
Sewerage sludge and residues including nightsoil and septic tank sludge	×	×	×	×	×	✓
Soils contaminated with a listed waste	×	×	×	×	×	✓
Tyres	×	×	×	×	×	✓
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	×	×	✓	×	×	×
Waste mineral oils unfit for their original intended use	×	×	✓	×	×	×

✓ Activity authorised by EPL 188 × Activity not authorised by EPL188

2.2 Site Layout

At the end of this monitoring period the Site included used putrescible waste landfill cell (Stage 5), inert waste landfill cell (Stage 2), waste transfer station, recycle shop, mulching/processing facility for green waste, leachate management system and landfill gas management system.

- The Stage 3 and 4 putrescible waste landfill cells reached capacity and were capped during 2016 and 2017, with the waste accepted by the Stage 5 cell currently approaching capacity, where waste has started diverting to the recently constructed Stage 6 landfill cell.
- The Stage 3, 4, and 5 landfill cells are lined and have a leachate collection system. The leachate collected is irrigated back onto the cells, when possible. Leachate storage ponds store excess leachate until it can be applied back onto the landfill cells;
- The Stage 2 landfill cell, located in the north eastern portion of the Site is unlined and accepts inert waste (construction and demolition including asbestos). The Stage 1 landfill cell, located in the southeast is an historic unlined landfill, which is capped and not in use. Leachate from the unlined Stage 1 and 2 landfill cells is collected in an underground drain running north-south along the eastern edge of the cells. This then drains into a collection chamber 'LMP02', where it is pumped out and irrigated onto the capped Stage 1 cell;
- Green waste storage and mulching is undertaken on a pad south of Stage 5;
- A facility for the short-term storage of chemicals is located in the southern portion of the Site; and
- Renewable energy is generated on Site using landfill gas (methane) and provided to Darwin's power grid. The landfill gas management system involves capturing methane gas emissions from the landfill via a gas extraction system comprising vertical and horizontal wells drilled into the waste cells connected to a reticulation system. Condensate from the gas extraction system is pumped to disposal trenches within the Stage 2 landfill.

For more details on the disposal, storage and handling of different waste types refer to the SBWMF *Environmental Management Plan* (CoD, 2016), Sections 5.4 and 5.5, and for more details on landfill leachate management and gas management, refer to the SBWMF *Environmental Management Plan* (CoD, 2016), Section 5.6 *Water Quality Management*.

2.3 Environmental Setting

2.3.1 Climate

The regional climate is tropical monsoonal with a distinct wet season (November to April) and dry season (May to October). Average yearly rainfall is 1,723.3 mm, 80% of which occurs between December and March (Darwin Airport, BoM Station Site Number 014015).

2.3.2 Hydrology

Surface water from the eastern portions of the SBWMF flows towards the Meckitt Creek floodplain (see **Figure 2-1**) Flows from the western portion of the Site are towards the Leanyer Swamp and Buffalo Creek. Both Meckitt Creek and Buffalo Creek are mangrove-lined tidal inlets of Shoal Bay; a coastal embayment with extensive sand and mud flats.

2.3.3 Hydrogeology

Geology and groundwater aquifers beneath the Site are described in detail in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015).

The lithology encountered during groundwater bore drilling for the investigation comprised top soils (silts and clays), generally underlain by weathered (lateralised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9.0 to 20 m below the surface across most of the Site.

Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock. Bore yields are generally very poor; less than 5.0 L/sec. Seasonal groundwater levels measured as part of the SBWMF water monitoring plan are greater than 12 meters below ground level (m bgl) at the end of the dry season and usually within 2.0 m of the ground surface during the peak of the wet season.

Groundwater down-gradient of the SBWMF is saline due to its close proximity to the coast and tidal saline intrusion; see *the Groundwater Resources of the Darwin Area Map* (DIPE 2003). There are no groundwater

bores or groundwater uses down-gradient of SBWMF other than that potentially associated with environmental supply of groundwater seepage into wetlands and tidal inlets.

Higher yielding weathered and fractured carbonate rock aquifers occur in the wider region, with yields commonly greater than 5.0 L/sec. *The Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region Map* (NRETA 2008) identifies a high yielding carbonate aquifer south-east of the SBWMF, trending in a northerly direction. Groundwater from this aquifer discharges to the surface within the Holmes Jungle Nature Park and maintains streamflow through the dry season. This spring and associated shallow groundwater support the Holmes Jungle rainforest. Further to the southeast around the Knuckey Lagoon area, a large number of bores draw groundwater from this carbonate aquifer for domestic and agricultural purposes.

The carbonate rock aquifer and associated springs, Holmes Jungle rainforest and groundwater users are all located upgradient of the SBWMF. No significant areas of carbonate rock aquifer are located down-gradient of the SBWMF and no carbonate rocks were encountered during the installation of the 32 groundwater bores, to depths of up to 30 mbgl, across the Site for the hydrogeological investigation (URS 2016).

For detailed analysis of potential contamination pathways for leachate and other pollutants from the SBWMF towards potential human health and environmental receptors, refer to the *Shoal Bay Waste Disposal Site Conceptual Site Model* (URS 2016).

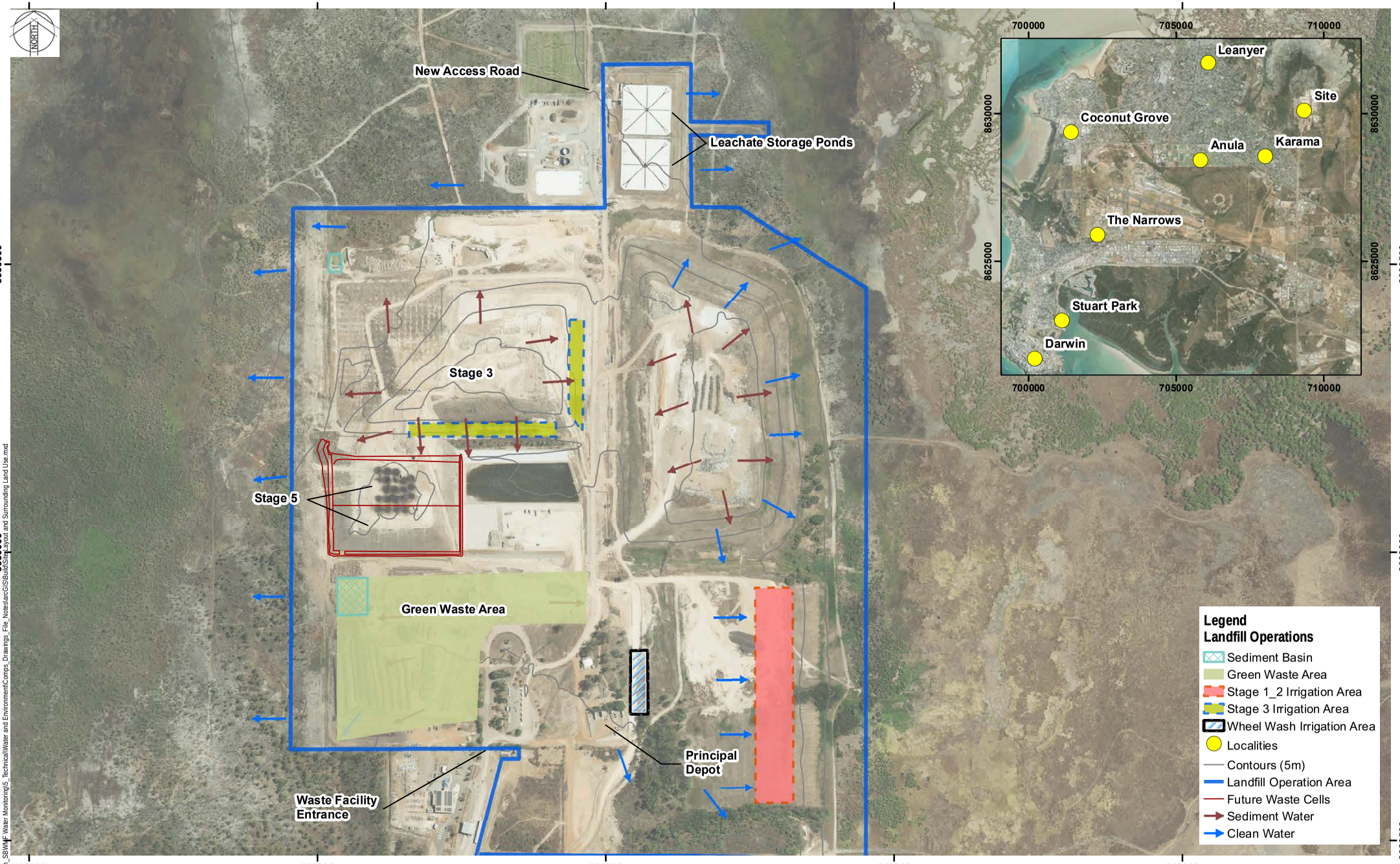
2.3.4 Environmental Values

EPL188-03 lists the following 'Environment Protection Objectives' (Part 4 of the WMPC Act), 'Beneficial Uses and Water Quality Standards' (section 73 of the NT Water Act) and 'environmental interests' that apply to the Site and immediate surrounds:

- *An Environment Protection Objective (EPO) is a statutory instrument to establish principles on which:*
  - *a) environmental quality is to be maintained, enhanced, managed or protected;*
  - *b) pollution, or environmental harm resulting from pollution, is to be assessed, prevented, reduced, controlled, rectified or cleaned up; and*
  - *c) effective waste management is to be implemented or evaluated.*
- *In accordance with section 18 of the WMPC Act a beneficial use, quality standard, criteria or objective declared under section 73 of the Water Act and in force is an environment protection objective for the purposes of the WMPC Act.*
- *Declared Beneficial Uses for the Darwin Harbour Area: Water Quality Objectives, NTG Gazette 29, June 2010; these include the beneficial uses of: environment, agriculture, cultural and rural stock and domestic. Of these, the 'environmental' beneficial use is the stringent in regards to water quality requirements given aquatic organisms are the most sensitive of these beneficial uses to water quality changes.*
- *Darwin Harbour Site of Conservation Significance (SOC 6)*

The SBWMF also lies within the Shoal Bay Site of Conservation Significance (SOC 8); see Factsheet available on the NT Government information and services website:

https://nt.gov.au/environment/environment-data-maps/important-biodiversity-conservation-sites/conservation-significance-list



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SITE LAYOUT AND SURFACE WATER FLOWS

CITY OF DARWIN

SHOAL BAY WASTE MANAGEMENT FACILITY
ENVIRONMNETAL MANAGEMENT PLAN

FIGURE 2-1

3 Monitoring

Groundwater, surface water and leachate water quality monitoring have been undertaken at the SBWMF as per the URS monitoring plan (2016) and subsequent EcOz monitoring plan since July 2016, when EPL188 was issued. Throughout this time, CoD initially commissioned EcOz Environmental Consultants (EcOz), assisted by Larrakia Nation Rangers, to carry out the monitoring, prior to engaging Cardno to undertake the monitoring activities.

Cardno has developed a specific safe work method statement (SWMS) and standard operating procedures (SOP) for soil, groundwater and surface water (applicable to leachate), which are always adhered to.

3.1 Methodologies

Cardno's suitably qualified scientist undertook groundwater, surface water, soil and dust deposition sampling detailed below, consistent with procedures laid out in the SWMP and in accordance with the following best practice industry standards and guidelines:

- NT EPA 'Guideline for Reporting on Environmental Monitoring'
- AS 4482.1-2005 "Guide to the investigation and sampling of sites with potentially contaminated soil, Part 1: Non-volatile and semi-volatile compounds";
- AS 4482.2-1999 "Guide to the sampling and investigation of potentially contaminated soil, Part 2: Volatile substances";
- AS 5667.1 "Water Quality-Sampling: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples";
- AS 5667.11-1998 "Water Quality-Sampling: Guidance on sampling of groundwater";
- Department of Environment and Regulation (DER), 2014, "Assessment and Management of Contaminated Sites";
- AS/NZS 5667.4:1998 "Water Quality Sampling - Part 4: Guidance on sampling from lakes, natural and man-made";
- AS/NZS 5667.6:1998 "Water Quality Sampling – Part 6: Guidance on sampling of rivers and streams";
- AN/NZS 5667.10:1998 "Water Quality Sampling – Part 10: Guidance on sampling of waste waters";
- DoH, 2014, Contaminated Sites Ground and Surface Water Chemical Screening Guidelines
- National Environment Protection Council (NEPC), 1999, *National Environmental Protection (Assessment of Site Contamination) Measure (as amended)*, registered May 2013;
- AS/NZS 3580.10.1-2016 Methods for sampling and analysis of ambient air - Determination of particulate matter – deposited matter – gravimetric method;
- AS/NZS 3580.1.1-2016 Methods for sampling and analysis of ambient air - Guide to Siting Air Monitoring Equipment;
- NEPC Schedule B (1): Guideline on the Investigation Levels for Soil and Groundwater.

3.1.1 General Monitoring Approach

During each monitoring round a team of two of Cardno's suitably qualified environmental scientists and hydrologists undertook groundwater and surface water monitoring in line with the aforementioned standards and SWMP. Ad Hoc soil sampling was also carried out during this reporting period. On each monitoring event, surveys were undertaken for up to 3 consecutive days. The monitoring procedures for groundwater and surface water monitoring were carried out concurrently and consisted of the following preliminaries:

- Prior to attendance to site preparation/update the Site Works Method Statement (SWMS) which include details of health and safety procedures, map showing location of sacred sites likely to have restrictions to access, and identification of required PPE for site conditions/requirements.
- At start of each field day and prior to each survey commencing, conduct a safety start meeting identifying potential hazards. Liaise with site manager to identify no-go zones regarding site's operations and other relevant safety information.

- Scope specific sampling procedures, data collection, and analysis are discussed in their respective sections below.

3.1.2 Ground Water Monitoring

During this monitoring period the following groundwater monitoring procedures were carried out by Cardno's suitably qualified personnel at each ground water monitoring location where hydrasleeve was the predominant sampling technique prior to the new SWMP:

- HydraSleeve sampling
  - HydraSleeves are deployed with top weight for sample collection to begin at the lowest point. HydraSleeve sampling devices are left in wells for a minimum of 4 hours to allow restabilisation of the well following the slight disturbance caused by sampler deployment.
  - Samples are then collected via continuous pull method at a rate allowing the water to pass through the check value into the sample sleeve.
  - Samples are discharged immediately (minimise changes in chemistry) via discharge tube.
- Low Flow Purging and sampling
  - Groundwater is purged utilising the "continue flow" technique using a low flow bladder pump.
  - Purging of each monitoring bore continues until groundwater field parameters [including pH, electrical conductivity (EC), oxidation reduction potential (ORP), dissolved oxygen (DO), turbidity and temperature] stabilise (as indicated by at least three consecutive measurements falling within +/- 5% of each other) and a sustainable sampling flow rate (i.e. minimal draw down) has been established to confirm that a representative sample of the Superficial Aquifer is collected.
- In situ temperature, pH, dissolved oxygen (DO), turbidity (ntu), electrical conductivity and redox (mV) is measured using a YSI Pro Plus Multiparameter Instrument
- Groundwater sampling can commence once the physiochemical parameters have stabilised, indicating that they represent natural groundwater in the aquifer.
- Samples collected for dissolved heavy metal analysis are filtered in the field using an in-line 0.45 micron (µm) filter to remove suspended solids and colloids
- Use of dedicated pump tubing at each groundwater well; and, thorough washing of all re-usable sampling equipment (i.e. pumps) and with detergent (Liquinox), then double rinsing with clean water and drying before the collection of each sample.
- Samples are collected directly in into appropriately labelled and preserved laboratory supplied bottles and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation.
- Sample containers, preservation procedures, sample storage requirements and holding times are undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998 and AS 4482.1 as appropriate). All holding times comply with the requirements set out in "Australian Standard AS/NZS 5567.1:1998 and AS 4482.1".

3.1.3 Storm / Surface Water and Leachate Monitoring Procedures

The following surface water sampling procedures were carried out by Cardno's suitably qualified personnel at each surface and storm water sampling location:

- In situ temperature, pH, dissolved oxygen (DO), turbidity (ntu), electrical conductivity and redox (mV) shall be measured using a YSI Pro Plus Multiparameter Instrument or equivalent
- The specific method of sampling adhered to those specified in and SWMP;
- Samples are collected directly in into appropriately labelled and preserved laboratory supplied bottles and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation.
- Surface water samples collected for dissolved heavy metal analysis are filtered in the field using an in-line 0.45 micron (µm) filter to remove suspended solids and colloids.
- Sample containers, preservation procedures, sample storage requirements and holding times are undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998 and AS 4482.1 as appropriate). All holding times comply with the requirements set out in "Australian Standard AS/NZS 5567.1:1998 and AS 4482.1".

- Use of dedicated disposable sampling equipment at each surface water location; and, thorough washing of all re-usable sampling equipment with detergent (Liquinox), then double rinsing with clean water and drying before the collection of each sample.

3.1.4 Floodplain Sediment Procedures

Currently the monitoring plan and assessment of offsite impacts to environmental receivers is in a state of review and is due to be implemented during 2022 (EcOz, 2021b). As part of offsite impact assessments, it is necessary to analysis the sediments chemistry of floodplains surrounding the SBWMF, however the proposed sampling points 'BCFP01' and 'MCFP01' (seen crossed out in red in **Figure 3-1**) lie with in an uncleared Unexploded Ordinance (UXO) area. Cardno therefore advanced two new locations outside of the uncleared UXO are following existing tracks to the edge of the flood plains before accessing the sites on foot (highlighted in orange).

Being that the objective is to assess 'offsite' impacts and the new proposed locations could potentially be considered too close to the contamination source to assess its linkage/pathway to offsite receptors. However, as the floodplain area is data deficient with regard to soil/sediment chemistry and the obvious safety implications of entering the uncleared UXO area, it was considered justified to sample these safer, closer locations to provide the opportunity to delineate source-pathway-receptor linkages even closer to site.

During this monitoring period the following soil sampling procedures were carried out by Cardno's suitably qualified personnel at newly proposed floodplain sampling locations seen in :

- Surficial sediment samples (e.g. top 200 mm) shall be collected from each accessible soil sampling location;
- Samples will be collected directly in into appropriately labelled and preserved laboratory supplied bottles and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation.
- Sample containers, preservation procedures, sample storage requirements and holding times will be undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998 and AS 4482.1 as appropriate). All holding times will comply with the requirements set out in "Australian Standard AS/NZS 5567.1:1998 and AS 4482.1".

3.1.5 Quality Assurance / Quality Control

QA/QC samples are collected at the frequency detailed in the SWMP and analysed for the same analytes as the primary samples:

- Field duplicate (intra-laboratory) at 1 per 10 primary water samples
- Field triplicate (inter-laboratory) at 1 per 10 primary water samples
- Field blank (one per event)

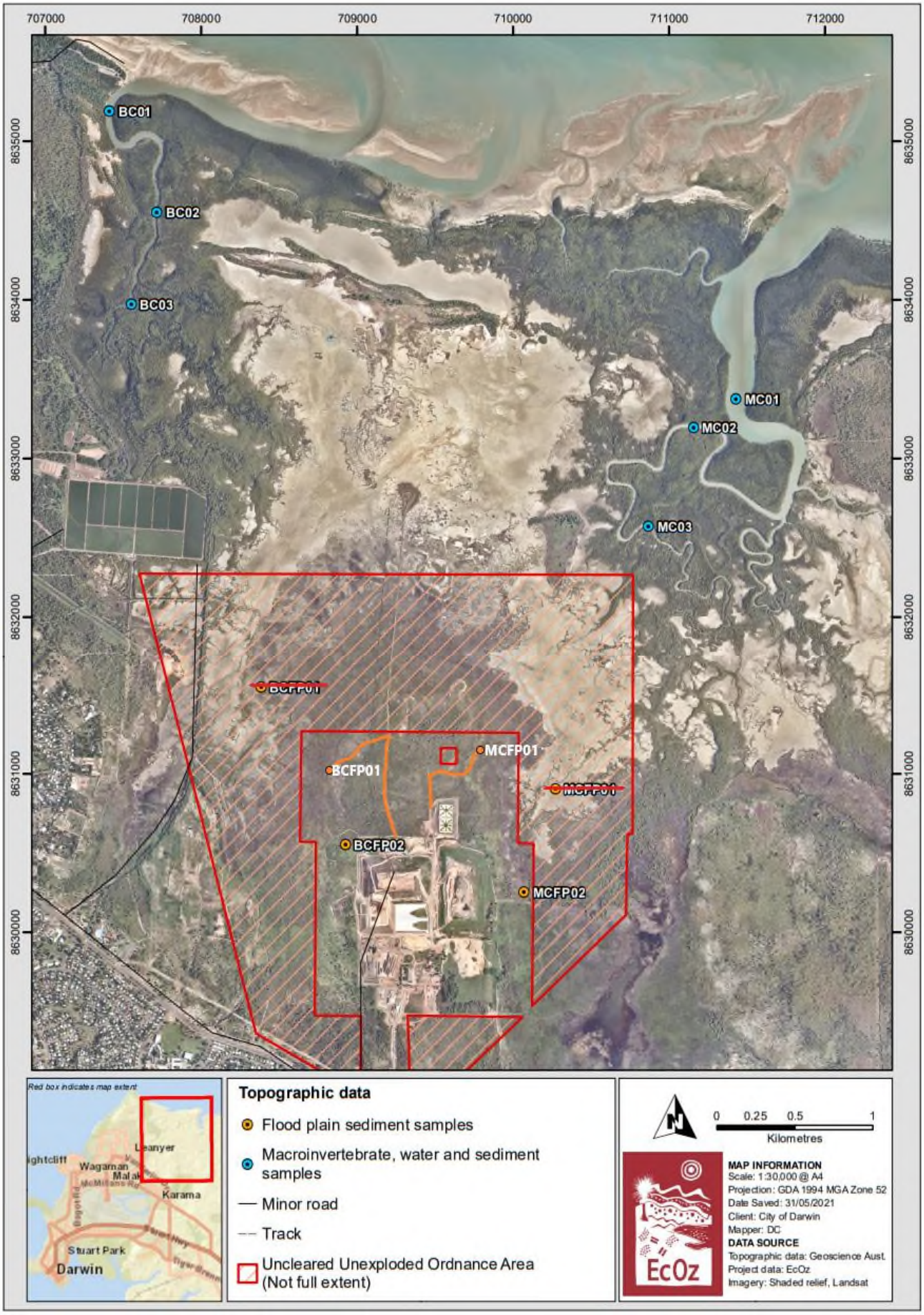


Figure 3-1 Alternative floodplain sediment sampling locations (Source: EcOz, 2021b)

3.2 Monitoring Sites

The current network of monitoring sites relevant to this review period includes 10 leachate sites, 43 groundwater sites, and 9 surface water and stormwater sampling sites. Each monitoring network is described in detail in their respective sections below.

3.2.1 Leachate Monitoring Network

Leachate sampling sites allow for the characterisation of contaminant concentrations in landfill leachate to allow for comparison with groundwater and surface water samples. The leachate sampling locations are detailed in **Table 3-1** and include:

- Deleaching Well (DW) DW2 - collects leachate from the south-west corner of the Stage 3/4 landfill;
- DW3 - collects leachate from the north-west corner of the Stage 3/4 landfill;
- Stage 3 leachate sump (TC Sump) - collects leachate from the eastern side of the Stage 3/4 landfill;
- DW5 - collects leachate from the western side of the Stage 5 landfill;
- DW6 - collects leachate from the south-west corner of the Stage 5 landfill;
- Leachate Pond (LP) LP01 - Northern leachate storage pond;
- LP02 - Southern leachate storage pond; and
- LMP02 - Sump at the end of a trench that runs along the western side of the Stage 1 and Stage 2, landfills and collects leachate from these landfills.

Table 3-1 Leachate Sampling Locations

Site ID	Easting (m)	Northing (m)	Location	Source
DW2	709029	8630459	Deleaching well on southwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW3	709038	8630216	Deleaching well on northwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW5	709023	8630122	Deleaching well on west side of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW6	709041	8630039	Deleaching well on southwest corner of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
TC Sump	709465	8630233	Sump on southeast corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
LMP02	709938	8629759	East of Stage 1	Sump that receives leachate from Stage 1 and 2 landfills via an interception trench that runs north-south along the eastern edge of the Stage 1 and 2 landfills.
LP01	709534	8630726	Northern leachate storage pond	Represents leachate in northern storage pond
LP02	709531	8630713	Southern leachate storage pond	Represents leachate in southern storage pond

3.2.2 Groundwater Monitoring Network

Ground water monitoring bores provide an indication of landfill leachate and/or other contaminants associated with SBWMF operations migrating from site in groundwater down gradient. The 43 groundwater monitoring bores to be monitored under EPL188-03 and bores previously monitored in line with the URS WMP are detailed in **Table 3-2**, and comprise:

- A total 41 bores at 22 locations across the site, with up to 3 bores (nested) at some locations. Installation of this monitoring network began in 2015 to inform a hydrogeological investigation (URS 2015) and development of a CSM (URS 2016). Since then additional clustered have been installed in 2019 and 2021 to inform groundwater impacts from newly constructed Stage 6 landfill and future leachate treatment infrastructure. Generally, each of the 22 locations includes a shallow bore screened between 1.5 and 3 m

below ground level (mbgl), and a deeper bore screened between 9 and 12 mBGL. Three of the locations have a third bore screened at 30 mBGL. The ID's for these bores are prefixed with a 'GW' and suffixed with a -3, -12 or -30 to indicate bore screening depth.

> Four bores of the current monitoring network installed prior to the URS (2015) hydrogeological investigation prefixed with a 'WW' with varying screened intervals; all less than 10 m deep.

> The most recent installation includes GW19 and GW20 (renamed from GWI5 and GWI6) which represent water from underneath the two landfill stages (stage 5/6 ad stage 2). As they have not been installed with monument and complete monitoring well infrastructure, they do not have TOC and other bore related information.

Table 3-2 Monitoring Bore Locations and Construction Details

Bore	Easting (m)	Northing (m)	Monument Elevation (m AHD)	PVC Elevation (m AHD)	Ground Elevation (m AHD)	Screened Interval (m bgl)	Screened Interval Lithology
GW1-3	709564	8631004	8.71	8.63	8.02	1.5-3	Siltstone
GW1-12	709566	8631004	8.71	8.59	8.00	9-12	Siltstone
GW2-3	709629	8630835	8.06	7.94	7.33	1.5-3	Siltstone
GW2-12	709631	8630835	8.08	7.94	7.28	9-12	Siltstone
GW3-3	709652	8630746	9.94	9.80	9.12	1.5-3	Siltstone
GW3-12	709654	8630746	9.87	9.82	9.10	9-12	Siltstone
GW4-3	709775	8630634	5.65	5.49	4.88	1.5-3	Siltstone
GW4-12	709776	8630633	5.61	5.44	5.36	9-12	Siltstone
GW4-30	709777	8630631	5.50	5.20	5.33	15-21	Gravelly sand, Sandstone
GW5-3	709880	8630224	5.51	5.41	4.70	1.5-3	Siltstone
GW5-12	709880	8630226	5.48	5.33	4.70	9-12	Siltstone, Gravelly Clay
GW7-3	709900	8629992	5.18	5.03	4.33	1.5-3	Siltstone
GW7-12	709900	8629994	5.16	5.08	4.33	9-12	Siltstone, Sandy Silt
GW8-3	709896	8629708	5.42	5.28	4.65	1.5-3	Claystone
GW8-12	709896	8629708	5.37	5.22	4.62	9.1-12.1	Claystone, Sandstone
GW9-12	709660	8629469	16.18	15.93	15.44	9-12	Siltstone
GW10-3	709147	8629507	18.12	18.06	17.32	1.5-3	Siltstone
GW10-12	709149	8629507	18.13	17.98	17.37	9.1-12.1	Siltstone
GW11-3	709040	8629671	13.50	13.38	12.72	1.5-3	Siltstone
GW11-12	709042	8629671	13.52	13.38	12.84	9-12	Siltstone, Sandstone
GW12-3	709024	8629881	12.20	12.07	11.44	1.5-3	Siltstone
GW12-12	709024	8629883	12.22	12.04	11.50	9-12	Siltstone
GW12-30	709024	8629885	12.21	12.05	11.55	24-30	Sandstone
GW13-3	709017	8630175	12.93	12.88	12.32	3-4.5	Siltstone
GW13-12	709016	8630174	12.91	12.86	12.25	10-13.5	Siltstone
GW14-3	709013	8630423	6.78	6.73	6.09	1.5-3	Siltstone
GW14-12	709013	8630424	6.77	6.64	6.08	9-12	Siltstone
GW15-3	709230	8630599	11.27	11.06	10.44	1.5-3	Siltstone
GW15-12	709233	8630599	11.20	11.04	10.44	9-12	Siltstone
GW16-3	709493	8630030	TBC	TBC	TBC	1.5-3	Sandy Claystone
GW16-12	709494	8630025	TBC	TBC	TBC	9-12	Siltstone
GW16-30	709495	8630021	TBC	TBC	TBC	30	Siltstone

Bore	Easting (m)	Northing (m)	Monument Elevation (m AHD)	PVC Elevation (m AHD)	Ground Elevation (m AHD)	Screened Interval (m bgl)	Screened Interval Lithology
GW17-3	709418	8630692	TBC	TBC	TBC	3	-
GW17-12	709418	8630691	TBC	TBC	TBC	12	-
GW17-30	709418	8630691	TBC	TBC	TBC	30	-
GW18-3	709464	8630729	TBC	TBC	TBC	3	-
GW18-12	709464	8630728	TBC	TBC	TBC		-
GW19	708952	8630107	-	-	-	-	-
GW20	709811	8629975	-	-	-	-	-
WW1	709471	8630255	-	16.60	15.90	0-6.3	-
WW6	709047	8630478	-	7.46	6.76	0-20.4	-
WW9	709016	8630598	-	7.09	6.39	1-9.8	Siltstone
WW13	709457	8630598	+0.8	+0.7	Not available	1-10	Siltstone

3.2.3 Stormwater and Surface Water Monitoring Network

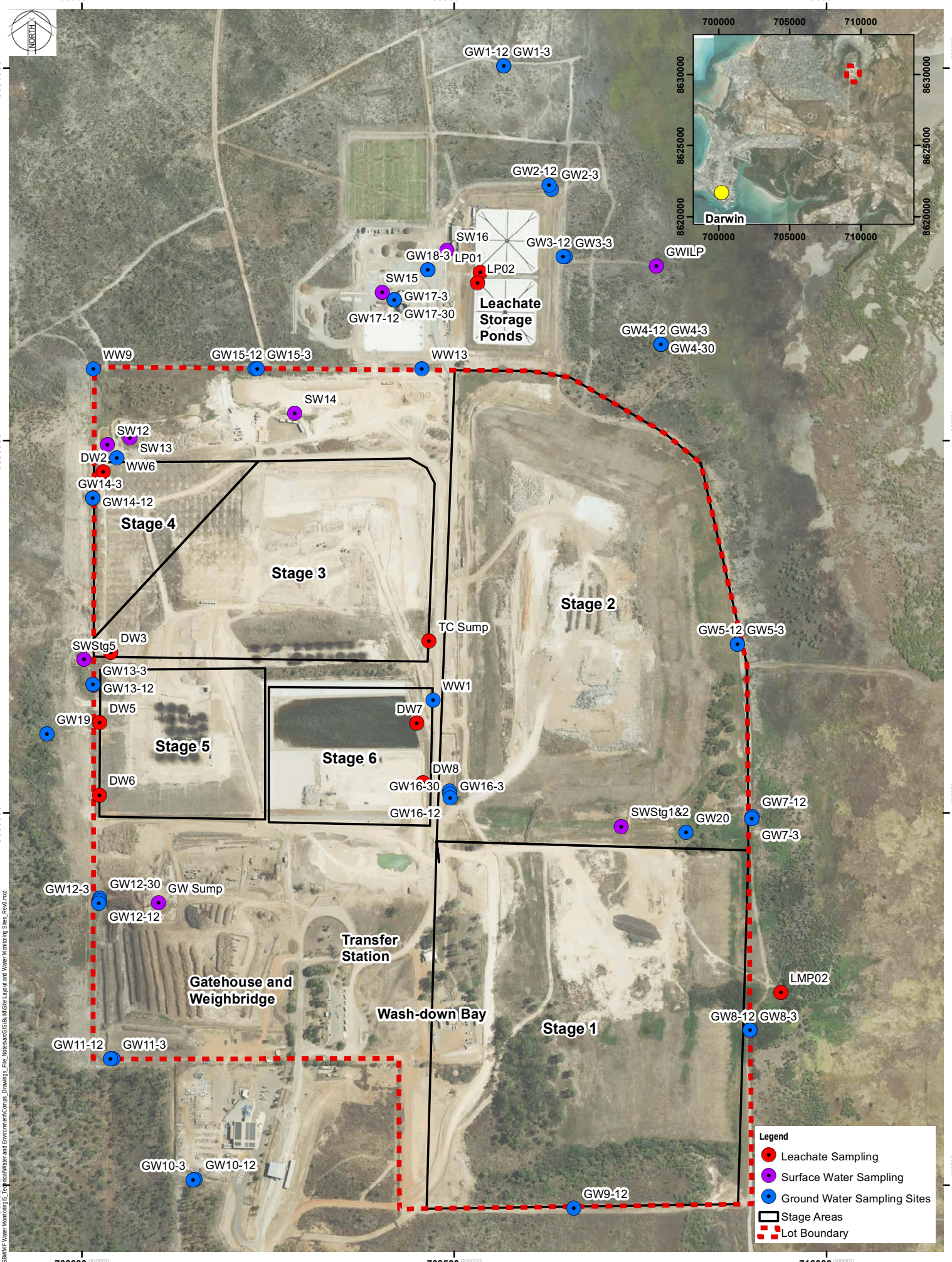
Surface water sampling locations provide an indication of landfill leachate and/or other contaminants associated with SBWMF operations that have the potential flow downstream and offsite affecting surrounding receptors. The surface water monitoring sites are detailed in **Table 3-3** and include:

- Wheel Wash Sump - collects the wash-down water from the bunded area used to wash commercial waste disposal vehicles;
- Water outfall from Stage 1 and Stage 2 landfills (STG1 & 2) - surface water drain along the western edge of the Stage 1 and Stage 2 landfills;
- Water outfall from Stage 3 and Stage 5 landfills (SWStg5) - surface water drain along the western edge of the Stage 3 and Stage 5 landfills
- Greenwaste (GW) Sump - collects surface water drainage from the green waste processing area; and
- SW12, SW13 and SW14 - receive surface water runoff (and potentially seepage) from the Stage 3 and 4 landfill cells.
- SW12, SW13 and SW14 - receive surface water runoff

Table 3-3 Storm water and Surface Water Monitoring Locations

Site ID	Easting (m)	Northing (m)	Location	Source
SWStg1&2 (formerly STG1&2)	709448	8629979	Surface drain between Stage 1 and Stage 2	Receives surface water runoff from central SBWMF areas
SWStg5	709003	8630206	Northwest of Stage 5	Receives surface water runoff from central Stage 3 and Stage 5 landfills.
GW Sump	709102	8629880	Sump within green waste processing and storage area	Receives surface water runoff from green waste processing and storage area. Possibly also surface runoff from the Stage 3 and 5 landfills.
GWILP	709771	8630733	East of the leachate ponds	Receives surface runoff from the existing leachate ponds.
SW12	709035	8630495	Catchment dam at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells
SW13	709065	8630504	Catchment dam at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells

Site ID	Easting (m)	Northing (m)	Location	Source
SW14	709287	8630536	Catchment dam north of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the western landfill cells
SW15	709405	8630699	North of leachate treatment	Receives runoff from the new leachate treatment plant
SW16	709490	8630756	West of leachate treatment plant	Receives runoff from the new leachate treatment plant



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Cardno

<Office Location> Tel. <xx xxxx xxxx>

Date
23/02/2022

Size
A3

Scale
1:4,500

0 25 50 75 100Meters

SITE LAYOUT & WATER MONITORING SITE LOCATIONS

CITY OF DARWIN
SHOAL BAY WASTE MANAGEMENT FACILITY
ENVIRONMNETAL MANAGEMENT PLAN
FIGURE 3-2

FILE: K:\Projects\CW1121900_City of Darwin_SBWMF Water Monitoring\5_Technical\Water and Environment\Comps_Drawings_File_Notes\arcGIS\Build\Site Layout and Water Monitoring Sites_Rev0.mxd

3.3 Sampling Frequency

EPL188-03 stipulates sampling frequencies and analysis for each sampling location provided in **Appendix A**. The specific sites actually sampled each month vary concurrent with seasonal changes in rainfall, surface water flows and groundwater levels. The availability of sites for sampling throughout the year (i.e. availability of water to sample) confirmed in previous annual reviews (Cardno, 2020, Cardno, 2021) is summarised as follows:

- All leachate sites (DW2, DW3 and LMP02) and the wheel wash sump can be sampled throughout the year;
- The GW Sump can usually be sampled throughout the wet season, between the months of September and May;
- The surface water site SW12 is a sediment dam that holds water throughout the wet season and well into the dry season i.e. is usually only dry from June to September;
- The surface water sites STG1&2 only have water and can be sampled immediately after heavy rainfall at the peak of the wet season i.e. January and February;
- During the dry season, most of the shallow 3.0 m deep bores, and a large number of the 12 m deep bores are dry i.e. groundwater levels drop below the bottom of the bore;
- The established deep bores GW4-30, GW16-30 and GW12-30 are known to contain water throughout the year, with standing water levels (SWLs) of up to 12 m bgl at the end of the dry season (at GW12-30) and within 6.0 m of the ground surface during the wet season. GW4-30, located close to the swamp northeast of the SBWMF, is often artesian throughout the wet season and only drops to a maximum 3.0 m bgl during the dry season.
- In addition to the three deep bores mentioned above, the following bores also contain groundwater throughout the dry season and can be sampled:
  - GW-5-12;
  - GW6-12;
  - GW7-12;
  - GW8-12; and
  - GW16-12.
- Newly installed wells GW17-30 and GW18-12 west of the leachate treatment ponds have been sampled through the dry season thus far.

Sampling is undertaken during the first week of every month, representative of water quality for the previous month, i.e. sampling during the first week of November represents October.

3.4 Parameters measured

Analysis suites prescribed by EPL-188-03 and laid out in SWMP are provided in **Appendix A**. In addition to the aforementioned sampling suites, monthly sampling of groundwater and surface water sites as per EPA304-01 for initial 12 months (April 2021 to March 2022) are detailed in **Table 3-1** below. **Table 3-2** provides which parameter suite was analysed during each monitoring round from October 2021 to December 2021.

Table 3-1 EPA304-01 Monthly Sampling Analysis

New Monitoring Locations	Analysis Details
GW18-3 GW18-12 GW18-30 GW17-3 GW17-12 SW15 SW16	The following parameters are assessed in new groundwater and surface water sampling locations: *In situ field parameters* ▪ Temperature ▪ Dissolved oxygen (DO) ▪ Electrical conductivity (EC) ▪ Total dissolved solids (TDS) ▪ Salinity ▪ pH ▪ Oxidation-reduction potential (ORP)

New Monitoring Locations	Analysis Details
	▪ Turbidity *Laboratory Testing* ▪ Ammonium of nitrogen (NH_4) ▪ Chemical oxygen demand (COD) ▪ Total dissolved solids (TDS) ▪ Total organic carbon (TOC) ▪ Major Ions (Sodium, Potassium, Magnesium, alkalinity, chloride, sulfate) ▪ Explosives - TNT and RDX ▪ PFAS ▪ Glyphosate ▪ Nutrients (nitrogen compounds) ▪ Dissolved heavy metals (NEPM suite 15 metals plus Fe, CrVI) ▪ Faecal coliforms and E. coli ▪ Polychlorinated biphenyls (PCBs) ▪ Organochlorine pesticides (OCP) ▪ Organophosphate pesticides (OPP) ▪ Volatile organic compounds (VOCs) ▪ Total recoverable hydrocarbons (TRH) ▪ Benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) ▪ Polycyclic aromatic hydrocarbons (PAHs) ▪ Phenolic compounds ▪ Volatile fatty acids (VFAs) ▪ Absorbable organic halide (AOX)

Table 3-2 Water Quality Analysis Schedule October 2020 – December 2021

Monitoring Event	Monitoring Schedule	Analysis Suite
October 2021	EPL188-03 and EPA304-01	Quarterly
November 2021	EPL188-03 and EPA304-01	Monthly
December 2021	EPL188-03 and EPA304-01	Monthly (*annual schedule included due to delayed start to 2022 sampling campaign)

3.5 Assessment Criteria

Assessment Criteria relevant to water and leachate have remained consistent with the below details during this monitoring review period.

3.5.1 Water Quality

Surface water trigger values prescribed by Attachment 3 of EPL188-03 (**Appendix A**) have been informed by the following guidelines:

- *Darwin Harbour Water Objectives (Shoal Bay upper area marine ambient water quality*) trigger values; and
- *Australian and New Zealand Guidelines (ANZG) for Fresh and Marine Water Quality* (2018) default guideline values (DGVs) for protection of 90% of marine ecosystems. These criteria aim to better assess the potential risk to surrounding environmental receptors.
- *PFAS National Environmental Management Plan v2.0* (HEPA, 2020), 90% species protection – highly disturbed systems in interim marine water (PFOS – 2 µg/L and PFOA – 632 µg/L)

The aforementioned guidelines currently reference freshwater values in lieu of interim marine guidelines, using the nationally agreed process under the *Australian and New Zealand Guidelines for Fresh and Marine*

Water Quality where PFOS and PFOA are the only PFAS species with guidelines values for aquatic ecosystems.

Pursuant to EPL 188-03, if at the time of review, groundwater, surface water and/or leachate quality issues have been identified (i.e. trigger levels are reached) then these issues will be raised formally with the CEO and NT EPA, provided that:

- Trigger levels have been exceeded over three consecutive monitoring events;
- A trigger level is exceeded greater than or equal to two times the trigger value; or
- A trigger level is exceeded at a median value over six consecutive monitoring events.

3.5.2 Floodplain Sediment

Flood plain sediment has been assessed against the following best practice industry guidelines:

- National Environment Protection Measure (NEPM 2013), *Environmental Screening Levels (ESLs) for Areas of Conservation Significance;* and
- National Environment Protection Measure (NEPM 2013), *ELSs for Commercial and Industrial.*

3.5.3 Emissions

Emission values have been previously compared against the emission limits stipulated in Attachment 7 of EPL188-03 but were not assessed by Cardno during this monitoring period.

4 Results

All raw water quality results (groundwater, surface water and leachate) obtained during the reporting period October 2021 – December 2021 are provided in **Appendix B**. Laboratory analysis reports produced during Cardno's quarterly sampling activities are provided in **Appendix C**.

4.1 Rainfall and Site Conditions

The availability of water for sampling at a number of groundwater and surface water sites is dependent on rainfall described in Section 2.3. Surface only water flows in stormwater drains across the site during and immediately after rainfall although surface water catchments such as 'SW12,13,14' and 'GW Sump' hold water for longer periods. Newly prescribed stormwater sampling sites SW15, SW16, SWStg1&2 and SWStg5 have only provided for sampling during December since their introduction to the monitoring program.

During this monitoring period the closest weather station to the site (Darwin Airport, BoM Station Site Number 014015) recorded a mean rainfall of 0.73mm/day in October, 4.2mm/day in November and 12.3mm/day in December.

4.2 Field Observations

4.2.1 Groundwater

Groundwater at SBWMF is recharged via direct infiltration of rainfall and/or runoff making groundwater levels in the shallow aquifer highly reactive to rainfall totals.

Dry or inaccessible wells and SWLs of groundwater bores sampled during each monitoring event of this reporting period are provided below in **Table 4-1**.

Table 4-1 Standing Water Levels for Bores Sampled

Monitoring Event	Dry or Inaccessible Groundwater Bore	Standing Water Levels (mbgl)
October 2021	WW1, WW13, GW1-3, GW1-12, GW9-12, GW15-12, GW3-3, GW4-3, GW4-12, GW17-3, GW17-12. GW18-3, GW13-3, GW12-3, GW10-3, GW10-12, GW11-3, GW11-12	Min: 1.18 at GW2-3 Max: 11.59 at GW13-12
November 2021	WW1, WW13, GW10-3, GW10-12, GW11-3, GW15-3, GW3-3, GW4-3	Min: 0.97 at GW7-12 Max: 11.02 at GW9-12
December 2021	GW11-12, GW19	Min: 0.3 at GW8-3 Max: 9.87 at GW13-12

4.2.2 Surface Water and Leachate

Surface only water flows in stormwater drains across the site during and immediately after rainfall although surface water catchments such as 'SW12,13,14' and 'GW Sump' hold water for long periods.

Surface water and leachate sites sampled during this reporting are provided below in **Table 4-2**. Noting that that sites not included were either not required by EPL188-03 sampling frequencies, dry or inaccessible during that month.

Table 4-2 Water and Leachate Locations Sampled

Monitoring Event	Surface Water Sites Sampled	Leachate Sites Sampled
October 2021	GW SUMP, SW12, SW13	LP02
November 2021	SW12, SW13. SW14,	LP02
December 2021	SW12, SW13, SW14, SW15, SW STG1&2, SW STG5, GWILP, GW SUMP	DW2, DW3, LP02, LMP02, TC SUMP

4.3 Laboratory Results

All Tabulated analytical results for groundwater, surface water, leachate and floodplain sediment sampled for this monitoring period are provided in **Appendix B**, laboratory certificates are provided in **Appendix C**. Exceedances of assessment criteria are summarised in the sections below.

4.3.1 Surface Water Trigger Level Exceedances

Table 4-3 to **Table 4-8** below present all surface water trigger value exceedances described in Section 3.5 "Assessment Criteria". The results highlighted in yellow indicate when the surface water trigger value was exceeded on three or more consecutive occasions as per EPL188-03 Condition 56.1. Results with an asterisk (*) indicate when the results are greater than or equal to two times the trigger value as per Condition 56.2.

Note that only trigger value exceedances are listed in the tables below. Where a concentration is not listed for a site or month and does not appear in the table, either the concentration was below the trigger value, the site was not sampled because it was dry or limited suites of analytes were assessed during that month. Refer to Section 4.2 above for the sites that were sampled during the reporting period.

4.3.1.1 Ammonia

Ammonia concentrations above adopted assessment criteria (20 µg/L) were observed at several surface water sampling locations provided in **Table 4-3**. Findings are summarised as follows:

- Exceedances of ammonia occurred in the sediment dams receiving runoff from the Stage 3, 4, 5 and 6 landfills (SW12, SW13, SW14, GW SUMP) and the storm water runoff from water from the Stage 1, 2 and 5 landfills (SWStg1&2, SW Stg5)
- Surface water and stormwater runoff impacts from leachate are indicated by consistently elevated ammonia concentrations up to 100 times the trigger value in sediment dams north of the site.
- GWILP designed to receive surface water run off from the leachate treatment ponds has experienced concentrations of Ammonia corresponding to untreated leachate (**Appendix B**) and is likely being contaminated by untreated leachate supply within the system.

Table 4-3 Exceedances of Ammonia above 20 µg/L

Location	Ammonia concentration (µg/L)		
	October	November	December
GW SUMP	1,800*	2,000*	770*
SW12	1,300*	480*	210*
SW13		2,700*	210*
SW14		220*	40*
SW STG1&2			110*
SW STG5			270*
GWILP			770,000*

Notes

- The results highlighted in yellow indicate when the trigger value was exceeded on three or more consecutive occasions as per Condition 56.1 of EPL188-03.
- Results with an asterisk (*) indicate when the surface water results are greater than or equal to two times the trigger value as per Condition 56.2 of EPL188-03.

4.3.1.2 Nitrogen

Total Nitrogen concentrations above adopted assessment criteria (300 µg/L) were observed at several surface water sampling locations provided in **Table4-4**. Findings are summarised as follows:

- Exceedances of Nitrogen occurred in the sediment dams receiving runoff from the Stage 3, 4, 5 and 6 landfills (SW12, SW13, SW14, GW SUMP) and the storm water runoff from water from the Stage 1, 2 and 5 landfills (SWStg1&2, SW Stg5)
- GWILP designed to receive surface water run off from the leachate treatment ponds has experienced concentrations of Ammonia consistent with untreated leachate (**Appendix B**).

Table 4-4 Exceedances of Nitrogen (Total) above 300 µg/L

Location	Nitrogen (Total) concentration (µg/L)		
	October	November	December
GW SUMP	16,900*	2,300*	6,400*
SW12	12,100*	5300*	3,500*
SW13	10,800*	7,400*	4,100*
SW14		4,800*	1,630*
SW STG1&2			1,610*
SW STG5			2,260*
GWILP			730,000*

Notes

- The results highlighted in yellow indicate when the trigger value was exceeded on three or more consecutive occasions as per Condition 56.1 of EPL188-03.
- Results with an asterisk (*) indicate when the surface water results are greater than or equal to two times the trigger value as per Condition 56.2 of EPL188-03.

4.3.1.3 Total Suspended Solids

Total Suspended Solids (TSS) concentrations exceeded the adopted assessment criteria (10 mg/L) at several surface water sampling locations provided in **Table 4-5**. Findings are summarised as follows:

> Exceedances of Nitrogen occurred in the sediment dams receiving runoff from the Stage 3, 4, 5 and 6 landfills (SW12, SW13, SW14, GW SUMP) and the storm water runoff from water from the Stage 1, 2 and 5 landfills (SWStg1&2, SW Stg5)

> Elevated TSS levels in surface water is likely due to inclusions of inorganic materials such as gravel, silt, and sand from topsoils across the site as TSS is consistently low in leachate across the site. Algae can also contribute to the TSS concentration

Table 4-5 Exceedances of TSS above 10 mg/L

Location	Total Suspended Solids (mg/L)		
	October	November	December
GW SUMP	140*	95*	230*
SW12	160*	36*	140*
SW13	110*	29*	370*
SW14			130*
SW15			15
SW STG1&2			12
SW STG5			480*

Notes

- The results highlighted in yellow indicate when the trigger value was exceeded on three or more consecutive occasions as per Condition 56.1 of EPL188-03.
- Results with an asterisk (*) indicate when the surface water results are greater than or equal to two times the trigger value as per Condition 56.2 of EPL188-03.

4.3.1.4 Copper

Recorded Copper concentrations exceeding the trigger value (0.003mg/L) for 90% species protection are provided in **Table 4-6** below and summarised as follows:

> Copper concentrations have been recorded over 3 times the trigger value and over three consecutive events during the wet season in the surface water in sediment dams receiving runoff from the Stage 3, 4, 5 and 6 landfills (SW12, SW13, GW SUMP)

Table 4-6 Exceedances of copper above the relevant trigger value of 0.003mg/L

Location	Copper concentration (µg/L)		
	October	November	December
GW SUMP	0.007*	0.005	0.005
SW12	0.011*	0.003	0.003
SW13	0.007*	0.003	0.003

Notes
- The results highlighted in yellow indicate when the trigger value was exceeded on three or more consecutive occasions as per Condition 56.1 of EPL188-03.
- Results with an asterisk (*) indicate when the surface water results are greater than or equal to two times the trigger value as per Condition 56.2 of EPL188-03.

4.3.1.5 Zinc

Zinc concentrations recorded above adopted assessment criteria of 0.0023mg/L were observed at a small number of surface water monitoring locations at the Site provided in **Table 4-7** below. Findings are summarised as follows:

> Zinc concentrations exceeded the relevant trigger value in surface water north of the Stage 3 and 4 landfills (SW12) and in the ground water sump south of Stage 5 during October;

> The inception point for the surface water of the leachate treatment ponds (GWILP) exceeded the relevant trigger value for Zinc during December.

Given the widespread nature of zinc exceedances, the groundwater is to a degree possibly naturally elevated in zinc. Leachate however, is also potentially further increasing zinc concentrations in water at the site.

Table 4-7 Exceedances of Zinc above the relevant trigger value of 0.023 mg/L

Location	Ammonia concentration (µg/L)		
	October	November	December
GW SUMP	0.39		
SW12	0.39		
GWILP			0.22*

Notes
- The results highlighted in yellow indicate when the trigger value was exceeded on three or more consecutive occasions as per Condition 56.1 of EPL188-03.
- Results with an asterisk (*) indicate when the surface water results are greater than or equal to two times the trigger value as per Condition 56.2 of EPL188-03.

4.3.2 PFAS Assessment

No stormwater and surface water monitoring locations exceeded the HEPA (2020) guideline value for 90% species protection for highly disturbed systems in interim marine water (PFOS – 2 µg/L and PFOA – 632 µg/L), only marginally exceeding the LOR (**Appendix B**)

This is consistent with historical observations of PFOS and PFOA concentrations at SBWMF.

4.3.3 Floodplain Sediment Sampling

Sediment sampled from the newly proposed floodplain sediment locations detailed in Section 3.1.4 did not produce any chemical concentrations above the ESLs for Areas of Conservation Significance; or ELSs for Commercial and Industrial land use (**Appendix B**). Results are summarised as follows:

> No BTEXN compounds were recorded above the limit of reporting (LOR) by laboratory analysis;

> No explosives (TNT, RDX) recorded concentrations above LOR by laboratory analysis;

> No PFAS compounds were recorded above the LOR by laboratory analysis;

4.4 Quality Assurance / Quality Control

All quality control/quality assurance procedures outlined in Section 3 and respective SOP's (**Appendix D**) were followed during field sampling as part of each monitoring event while all analysis was completed within holding times.

At each monitoring event relative percent difference (RPD) was calculated for primary, duplicate and triplicate samples where 30% RPD values infer precise data. Where the RPD was above 30%, the primary result was only used in further assessment if RPD was within 5 times the LOR and therefore remained acceptable.

The QA/QC review concluded that there are no significant systematic errors in the data collection process and therefore, the dataset used for the assessment is considered valid and complete.

5 Discussion of Results

Based on the results of contaminants measured in leachate, surface water and groundwater during the reporting period (in particular nutrients and metals), impacts from the migration of leachate in groundwater and surface water flowing from the Site are occurring to the southwest, west and northwest of the Stage 3, 4 and 5 landfills (SW STG5, SW12, SW13, SW14) and in the centre of the Site (SW STG1&2).

Consistent with previous reporting (Cardno, 2020, 2021) copper and zinc are the most prevalent metals often and significantly elevated in ground and surface waters across the Site. This appears to be attributed to a degree of natural background levels, with some impacts from the landfills increasing concentrations in locations east of the Site adjacent to the Stage 1 landfill, and west of the Site adjacent to the Stage 3, 4 and 5 landfills.

Soil chemistry analysed from the newly proposed floodplain sediment locations detailed in Section 3.1.4 which are closer to the SBWMF haven't produced any signs of contamination, however further soil chemistry trends will be better understood following future offsite sampling events.

These initial results provide justification that the alternative sites found closer to the SBWMF which avoid are suitable for assessing offsite impacts through floodplain sediment analysis. Routine soil and dust depositional sampling was not due for assessment during this monitoring period as per Attachment 8 of EPL188-03 (**Appendix A**) and will be reporting during subsequent monthly monitoring.

6 Conclusions and Recommendations

During this reporting period analysis suites and sampling frequencies have been implemented comply with the EPL188-03 and Soil & Water Monitoring Plan developed by EcOz (EcOz, 2021). EPL188-03 also stipulates the development of a surface water, sediment and biological monitoring plan for the adjacent Mickett Creek and Buffalo Creek environments which serve to assess offsite impacts which is due to be implemented in 2022 once suitability of sampling locations (i.e. floodplain sediment sampling locations discussed in this review) are confirmed.

Analytical results and the hydraulic gradient of the Site detailed in Section 2.3 of this report indicates the migration of leachate in groundwater and surface water flowing from the Site are occurring to the southwest of the stage 5 landfill; north west of the Stage 3 and 4 landfills; west of the Stage 1 landfill and between Stage 2 and 3 landfills.

Given the consistent widespread nature of Zinc exceedances in ground water and surface water across the Site, the soil and groundwater are potentially naturally elevated in Zinc. Monitoring of existing and/or installing of new upgradient monitoring bores would allow for a broader assessment of the area and evaluation of the contribution of SBWMF.

There were trigger value exceedances in several nutrients and metals from the storm and surface water sampling locations, however, trigger values derived from the Darwin Harbour Water Quality Objective may be considered too conservative to apply to SBWMF inland surface water monitoring locations and more suitable to the sampling locations to be implemented as part of the surface water, sediment and biological monitoring plan.

Sampling of the newly proposed floodplain sediment locations which avoid uncleared UXO areas are considered suitable to determine the extent of any source-pathway-receptor linkages between leachate from SBWMF and the sediment in the neighbouring floodplain environment.

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APPENDIX

A

SAMPLING SCHEDULE

Attachment 3 – Surface Water Monitoring Program and Trigger Values

	Sample Locations	Sample Locations								
	Site Code	SW12	SW13	SW14	GW Sump	SWStg1&2	SWStg5	GWILP	GWI5	GWI6
	Easting (m E)	709035	709065	709287	709102	709724	709003	709771	708952	709811
	Northing (m S)	8630495	8630504	8630536	8629880	8629982	8630206	8630733	8630107	8629975
Parameter	**Units**	**Trigger Value**	**Frequency**								
Field Measurement											
Flow	kL/day	-	-	-	-	-	M[3]	M[3]	C[4]	C[4]	C[4]
Water Level	measure	-	M	M	M	M[5]	-	-	-	-	-
pH	pH units	6 – 8.5[1]	M	M	M	M[5]	M[5]	M[5]	Q	Q	Q
Electrical Conductivity (EC)	µS/cm	-	M	M	M	M[5]	M[5]	M[5]	Q	Q	Q
Dissolved Oxygen (DO)	% saturation	80 – 100[1]	M	M	M	M[5]	M[5]	M[5]	Q	Q	Q
Temperature	ºC	-	M	M	M	M[5]	M[5]	M[5]	Q	Q	Q
Turbidity	NTU	-	M	M	M	M[5]	M[5]	M[5]	Q	Q	Q
Metals/Metalloids (filtered (0.45µm) and unfiltered)											
Boron (B)	µg/L	-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Cadmium (Cd)		1.4[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Chromium (Cr)[7]		20[6]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Cobalt (Co)		14[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Copper (Cu)		3[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Lead (Pb)		6.6[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Nickel (Ni)		200[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Zinc (Zn)		23[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Other											
Total Organic Carbon (TOC)	mg/L	-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Chemical Oxygen Demand (COD)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Total Suspended Solids (TSS)		10[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Total Dissolved Solids (TDS)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Major Ions											
Carbonate (CO_3)	mg/L	-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Bicarbonate (HCO_3)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Calcium (Ca)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Magnesium (Mg)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Potassium (K)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q

Sodium (Na)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Chloride (Cl)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Sulphate (SO_4)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Nutrients											
Ammonia (NH_3 as N)	µg/L	20[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Nitrate (NO_3)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Nitrite (NO_2)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Oxides of Nitrogen (NO_x)		20[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Total Nitrogen (TN)		300[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Total Phosphorous (TP)		30[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Filterable reactive phosphorous (FRP)		10[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q	Q	Q
Hydrocarbons											
Total Recoverable Hydrocarbons (TRH)	µg/L	-	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Benzene		900[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Toluene		-	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Ethylbenzene		-	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Xylene		-	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
Naphthalene		90[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
PFAS (per-and poly-fluoroalkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)											
PFOS	µg/L	2[8]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A
PFOA		632[8]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A	A	A

C – Continuous
M – Monthly
Q – Quarterly (January, April, July, October)
A – Annually (January)

[1] – Based on Darwin Harbour Water Objectives (Shoal Bay upper area marine ambient water quality)
[2] – Based on 90% species protection for marine waters ANZECC Water Quality Guidelines 2018 (ANZG 2018)
[6] – Based on Hexavalent chromium 90% species protection ANZECC Water Quality Guidelines 2018 (ANZG 2018)

[3] – Estimate the flow at the time of sampling
[4] – Using a flow meter
[5] – Only during months October to April
[7] – Analyse for Trivalent and Hexavalent Chromium if total chromium exceeds trigger value
[8] – Based on PFAS NEMP 2.0 however, trigger values for the latest NEMP must be used when available

Attachment 4 - Groundwater Monitoring Program

Parameter	Units	Frequency (all monitoring bores identified in Appendix 5)
Field Measurement		
Flow	kL/day	M[1]
Standing Water Level (SWL)	m AHD	M
pH	pH units	Q
Electrical Conductivity (EC)	µS/cm	Q
Dissolved Oxygen (DO)	% saturation	Q
Temperature	ºC	Q
Reduction Oxidation Potential (REDOX)	mV	Q
Metals/Metalloids (filtered (0.45µm))		
Arsenic (As)	µg/L	A
Boron (B)		Q
Cadmium (Cd)		A
Chromium (Cr)		Q
Cobalt (Co)		A
Copper (Cu)		Q
Lead (Pb)		Q
Lithium (Li)		A
Nickel (Ni)		Q
Vanadium (V)		A
Zinc (Zn)		Q
Major Ions		
Carbonate (CO_3)	mg/L	Q
Bicarbonate (HCO_3)		Q
Calcium (Ca)		Q
Magnesium (Mg)		Q
Potassium (K)		Q
Sodium (Na)		Q
Chloride (Cl)		Q
Sulphate (SO_4)		Q
Nutrients		
Ammonia (NH_3 as N)	µg/L	Q
Ammonium (NH_4)		Q
Nitrate (NO_3)		Q
Nitrite (NO_2)		Q
Oxides of Nitrogen (NO_x)		Q
Total Nitrogen (TN)		Q
Total Phosphorous (TP)		Q
Hydrocarbons		
Total Recoverable Hydrocarbons (TRH)	µg/L	A
Benzene		A
Toluene		A
Ethylbenzene		A
Xylene		A
Naphthalene		A
PFAS (per-and poly-fluoroalkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)		
PFOS	µg/L	Q
PFOA		Q
Other		
Chemical Oxygen Demand (COD)	mg/L	Q
Total Organic Carbon (TOC)		Q
Total Dissolved Solids (TDS)		Q
Organophosphate Pesticides	µg/L	A

Organochlorine Pesticides		A
Polychlorinated Biphenyls		A
Tributyltin Oxide		A
Phenols		A
Escherichia Coli	CFU 100mL	A
Enterococci		A

M – Monthly
Q – Quarterly (January, April, July, October)
A – Annually (January)
[1] – If the water level is above top of casing when measuring SWLs then estimate the flow.

Attachment 6 - Leachate Monitoring Program

		Sample Locations									
	Site Code	LP01	LP02	DW2	DW3	DW5	DW6	DW7[1]	DW8[1]	TC Sump	LMP02
	Easting (m E)	709534	709531	709029	709038	709023	709041	709450	709459	709465	709938
	Northing (m S)	8630726	8630713	8630459	8630216	8630122	8630039	8630121	8630042	8630233	8629759
Parameter	**Units**	**Frequency**									
Flow	kL/day	-	-	C[2]	C[2]	C[2]	C[2]	C[2]	C[2]	C[2]	C[2]
Water Level	measure	M	M	M	M	M	M	M	M	M	M
pH	pH units	Q	Q	B	B	B	B	B	B	B	B
Electrical Conductivity (EC)	µS/cm	Q	Q	B	B	B	B	B	B	B	B
Dissolved Oxygen (DO)	% saturation	Q	Q	B	B	B	B	B	B	B	B
Temperature	ºC	Q	Q	B	B	B	B	B	B	B	B
Turbidity	NTU	Q	Q	B	B	B	B	B	B	B	B
Metals/Metalloids (filtered (0.45µm) and unfiltered)											
Aluminium (Al)	µg/L	Q	Q	B	B	B	B	B	B	B	B
Arsenic (As)		Q	Q	B	B	B	B	B	B	B	B
Boron (B)		Q	Q	B	B	B	B	B	B	B	B
Cadmium (Cd)		Q	Q	B	B	B	B	B	B	B	B
Chromium (Cr)		Q	Q	B	B	B	B	B	B	B	B
Cobalt (Co)		Q	Q	B	B	B	B	B	B	B	B
Copper (Cu)		Q	Q	B	B	B	B	B	B	B	B
Iron (Fe)		Q	Q	B	B	B	B	B	B	B	B
Lead (Pb)		Q	Q	B	B	B	B	B	B	B	B
Lithium (Li)		Q	Q	B	B	B	B	B	B	B	B
Manganese (Mn)		Q	Q	B	B	B	B	B	B	B	B
Mercury (Hg)		Q	Q	B	B	B	B	B	B	B	B
Nickel (Ni)		Q	Q	B	B	B	B	B	B	B	B
Selenium (Se)		Q	Q	B	B	B	B	B	B	B	B
Vanadium (V)		Q	Q	B	B	B	B	B	B	B	B
Zinc (Zn)		Q	Q	B	B	B	B	B	B	B	B
Major Ions											
Carbonate (CO_3)	mg/L	Q	Q	B	B	B	B	B	B	B	B
Bicarbonate (HCO_3)		Q	Q	B	B	B	B	B	B	B	B
Calcium (Ca)		Q	Q	B	B	B	B	B	B	B	B
Magnesium (Mg)		Q	Q	B	B	B	B	B	B	B	B
Potassium (K)		Q	Q	B	B	B	B	B	B	B	B

Sodium (Na)		Q	Q	B	B	B	B	B	B	B	B
Chloride (Cl)		Q	Q	B	B	B	B	B	B	B	B
Sulphate (SO_4)		Q	Q	B	B	B	B	B	B	B	B
Nutrients											
Ammonia (NH_3)	µg/L	Q	Q	B	B	B	B	B	B	B	B
Ammonium (NH_4)		Q	Q	B	B	B	B	B	B	B	B
Nitrate (NO_3)		Q	Q	B	B	B	B	B	B	B	B
Nitrite (NO_2)		Q	Q	B	B	B	B	B	B	B	B
Oxides of Nitrogen (NOx)		Q	Q	B	B	B	B	B	B	B	B
Total Nitrogen (TN)		Q	Q	B	B	B	B	B	B	B	B
Total Phosphorous (TP)		Q	Q	B	B	B	B	B	B	B	B
Filterable reactive phosphorous (FRP)		Q	Q	B	B	B	B	B	B	B	B
Hydrocarbons											
Total Recoverable Hydrocarbons (TRH)	µg/L	Q	Q	B	B	B	B	B	B	B	B
Polycyclic Aromatic Hydrocarbons (PAHs)		Q	Q	B	B	B	B	B	B	B	B
Benzene		Q	Q	B	B	B	B	B	B	B	B
Toluene		Q	Q	B	B	B	B	B	B	B	B
Ethylbenzene		Q	Q	B	B	B	B	B	B	B	B
Xylene		Q	Q	B	B	B	B	B	B	B	B
Naphthalene		Q	Q	B	B	B	B	B	B	B	B
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)											
PFOS	µg/L	Q	Q	B	B	B	B	B	B	B	B
PFOA		Q	Q	B	B	B	B	B	B	B	B
Other											
Organophosphate Pesticides	µg/L	A	A	-	-	-	-	-	-	-	-
Organochlorine Pesticides		A	A	-	-	-	-	-	-	-	-
Polychlorinated Biphenyls		A	A	-	-	-	-	-	-	-	-
Tributyltin Oxide		A	A	-	-	-	-	-	-	-	-
Phenols		A	A	-	-	-	-	-	-	-	-
Chemical Oxygen Demand (COD)	mg/L	Q	Q	B	B	B	B	B	B	B	B
Total Suspended Solids (TSS)		Q	Q	B	B	B	B	B	B	B	B
Total Organic Carbon (TOC)		Q	Q	B	B	B	B	B	B	B	B
Total Dissolved Solids (TDS)		Q	Q	B	B	B	B	B	B	B	B
Escherichia Coli	CFU 100ml	A	A	-	-	-	-	-	-	-	-
Enterococci		A	A	-	-	-	-	-	-	-	-

C – Continuous
M – Monthly

Q – Quarterly (January, April, July, October)
B – Biannually (January, July)
A – Annually (July)

[1] - Sampling points for Stage 6 leachate collection only active once Stage 6 begins to accept waste
[2] – Using a flow meter

Attachment 7 Emissions Monitoring Program

Substance	Units	Emission Limit^	Frequency	Test Method^
Sample Plane Criteria	-	-	During commissioning and Two months after commissioning and Four months after commissioning then Quarterly (January, April, July and October)	TM-1
Oxides of Nitrogen (NO_x) (as NO_2)	mg/m^3	350		TM-11
Hydrogen Chloride	mg/m^3	100		TM-8
Carbon Monoxide	mg/m^3	125		TM-32
Carbon Dioxide	mg/m^3	-		TM-24
Fluorine compounds (as Hydrogen Fluoride)	mg/m^3	50		TM-9
Sulphuric acid mists	mg/m^3	100		TM-13
Dioxins and Furans	ng/m^3	0.1		TM-18
Type 1 and Type 2 substances in aggregate. antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, tin or vanadium or any compound containing one or more of those elements.	mg/m^3	1		TM-12 and TM-13 and TM-14
Cadmium (Cd) and cadmium compounds	mg/m^3	0.2		TM-14
Mercury (Hg) and mercury compounds	mg/m^3	0.2		TM-14
Volatile Organic Compounds (VOCs), as n-propane [1]	mg/m^3	40		TM-34 [1]
Chlorine (Cl_2)	mg/m^3	200		TM-7
Hydrogen Sulphide (H_2S) [2]	mg/m^3	5		TM-5 [2]
PFAS (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)	µg/L	- *		-
Ammonia – N [3]	mg/m^3	-		TM-3 [3]
Odour [4]	-	-		OM-7 [4]
Polychlorinated Biphenyls	mg/m^3	-		-
Sulphur Dioxide	mg/m^3	-		TM-4

* - No limit currently set. If further revisions of the PFAS NEPM include an emission limit then the new limit will apply.

^ - Based on the New South Wales Environmental Operations (Clean Air) Regulations 2010.

[1] - The prescribed method, TM-34, will be used with modification. A moisture removal trap will be placed in front of the solid sorbent media to prevent water from entering the media. Both the condensate captured in the trap and the sorbent media will be analysed for VOCs and the results will be combined and reported.

[2] - The prescribed method, TM-5, will be used with modification. A sample of exhaust gas will be passed through a buffer solution to remove any potential SO_2 present before being captured in a specialised gas sampling bag.

[3] - The prescribed method TM-3 will be used with modification. A moisture removal trap will be placed in front of the media to prevent water from entering the tube.

[4] - The odour samples bags will be diluted beyond the suggested limit in OM-7 (AS4323.3). This is required to avoid condensation forming in the sample bags.

Attachment 8 - Depositional Sampling Program

		Sample Locations			
	Site Code	DS01	DS02	DS03	DS04
	Easting (m E)	709187	709580	709788	709252
	Northing (m S)	8630904	8631014	8630614	8630601
Parameter	**Units**	**Frequency**			
Metals/Metalloids					
Aluminium (Al)	µg/L	B	B	B	B
Boron (B)		B	B	B	B
Chromium (Cr)		B	B	B	B
Cobalt (Co)		B	B	B	B
Copper (Cu)		B	B	B	B
Lead (Pb)		B	B	B	B
Lithium (Li)		B	B	B	B
Mercury (Hg)		B	B	B	B
Nickel (Ni)		B	B	B	B
Zinc (Zn)		B	B	B	B
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)					
PFOS	µg/L	B	B	B	B
PFOA		B	B	B	B
B – Biannually (January, July)					

Attachment 9 – Soil Sampling Program

		Sample Locations			
	Site Code	SS01	SS02	SS03	SS04
	Easting (m E)	709187	709580	709788	709252
	Northing (m S)	8630904	8631014	8630614	8630601
Parameter	**Units**	**Frequency**			
Metals/Metalloids					
Aluminium (Al)	µg/L	B	B	B	B
Boron (B)		B	B	B	B
Chromium (Cr)		B	B	B	B
Cobalt (Co)		B	B	B	B
Copper (Cu)		B	B	B	B
Lead (Pb)		B	B	B	B
Lithium (Li)		B	B	B	B
Mercury (Hg)		B	B	B	B
Nickel (Ni)		B	B	B	B
Zinc (Zn)		B	B	B	B
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)					
PFOS	µg/L	B	B	B	B
PFOA		B	B	B	B
B – Biannually (January, July)					

APPENDIX

B

OCT – DEC 2021 RESULTS

							Field ID	GW SUMP	GW12-12	GW12-30	GW13-12	GW14-12	GW14-3	GW16-12	GW16-3	GW16-30	GW17-30	GW18-12	GW2-12	GW2-3	GW3-12	GW4-30	GW5-12	GW5-3	GW7-12
							Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	9/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021
							LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043
							Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	**Chemical Name**	**Units**	**EQL**																				
Field	SWL	mbgl					-	9.17	5.26	11.59	2.77	1.75	3.35	2.61	9.95	10.99	6.63	3.47	1.18	7.56	1.76	1.77	2.36	1.44
	pH	pH		**6-8.5**	**6-8**		6.58	6.53	6.05	**5.81**	**5.4**	6.34	**5.34**	**5.3**	**5.46**	7.38	**5.71**	6.54	7.12	6.02	**5.97**	6	6.31	**5.53**
	Electrical conductivity	uS/cm					848	144.8	49.6	342.7	16764	16672	2420	628	182	44885	1351	23890	2138	4956	1275	3278	4334	8826
	Redox Potential	mV					100.8	266.2	256.7	63.4	179.3	171.7	184.7	173.3	210.9	125.4	31.8	109.7	194.7	210.7	170	118.5	140	126.6
	Dissolved Oxygen	%S		**80-100**			**42.8**	66.8	56.6	29.4	72.6	61.4	8.6	13.6	65.7	32.8	96.5	15	108.8	102.7	75.1	53.2	79.5	46.6
	Temp	oC					29.7	28.3	28.3	29.4	27.5	27.8	29.5	30.3	29.8	28.2	29.2	30.2	31.1	28.7	28.5	28.9	29.2	28.2
	Turbidity	ntu					369.7	7.8	1.87	-	2.33	3.91	21.6	15.3	6.67	7.7	26.5	6.3	2.84	3.17	2.61	0.91	8.58	2.26
	Tokuthion	mg/L	0.002				-	-	-	-	-	-	-	-	-	<0.002	<0.002	-	-	-	-	-	-	-
	Acetic Acid	µg/L	5000				-	-	-	-	-	-	-	-	-	9900	11,000	-	-	-	-	-	-	-
	Aminomethyl phosphonic acid	µg/L	10				-	-	-	-	-	-	-	-	-	80	<10	-	-	-	-	-	-	-
	Valeric Acid	µg/L	5000				-	-	-	-	-	-	-	-	-	<5000	<5000	-	-	-	-	-	-	-
PFAS	(N-EtFOSA)	mg/L	0.00005				-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
	Perfluoronanesulfonic acid (PFNS) (trace)	µg/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(8:2 FTSA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(10:2 FTSA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(4:2 FTSA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(N-EtFOSAA)	UG/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-EtFOSE)	UG/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-MeFOSAA)	UG/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-MeFOSE)	UG/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	N-methylperfluoro-1-octanesulfonamide (N-MeFOS	UG/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Sum of PFASs (n=30)*	UG/L	0.1				-	<0.1	<0.1	0.6	<0.1	1.21	0.35	1.2	<0.1	<0.1	0.27	<0.1	<0.1	<0.1	<0.1	<0.1	0.28	0.19
	Sum of US EPA PFAS (PFOS + PFOA)*	UG/L	0.01				-	<0.01	<0.01	0.19	<0.01	0.18	0.05	0.35	<0.01	<0.01	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.17
	Sum of WA DWER PFAS (n=10)*	UG/L	0.05				-	<0.05	<0.05	0.6	<0.05	1.16	0.34	1.17	<0.05	<0.05	0.27	<0.05	<0.05	<0.05	<0.05	<0.05	0.23	0.19
	Perfluorobutanesulfonic acid (PFBS)	UG/L	0.01				-	<0.01	<0.01	0.16	<0.01	0.33	0.03	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01
	Perfluorobutanoic acid (PFBA)	UG/L	0.05				-	<0.05	<0.05	0.07	<0.05	0.16	0.07	0.16	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Perfluorodecanesulfonic acid (PFDS)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorodecanoic acid (PFDA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorododecanoic acid (PFDoDA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroheptanesulfonic acid (PFHpS)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroheptanoic acid (PFHpA)	UG/L	0.01				-	<0.01	<0.01	0.02	<0.01	0.05	0.03	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorohexanesulfonic acid (PFHxS)	UG/L	0.01				-	0.02	<0.01	0.05	<0.01	0.07	0.06	0.11	<0.01	<0.01	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.02
	Perfluorohexanoic acid (PFHxA)	UG/L	0.01				-	<0.01	<0.01	0.07	<0.01	0.17	0.05	0.16	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
	Perfluorononanoic acid (PFNA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorooctane sulfonamide (FOSA)	UG/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Perfluorooctanoate (PFOA)	UG/L	0.01			**632**	-	<0.01	<0.01	0.06	<0.01	0.12	0.05	0.19	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02
	Perfluorooctanesulfonic acid (PFOS)	UG/L	0.01			**2**	-	<0.01	<0.01	0.13	<0.01	0.06	<0.01	0.16	<0.01	<0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.15
	Perfluoropentanesulfonic acid (PFPeS)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
	Perfluoropentanoic acid (PFPeA)	UG/L	0.01				-	<0.01	<0.01	0.04	<0.01	0.2	0.05	0.16	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
	Perfluoropropanesulfonic acid (PFPrS)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
	Perfluorotetradecanoic acid (PFTeDA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorotridecanoic acid (PFTrDA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroundecanoic acid (PFUnDA)	UG/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Sum (PFHxS + PFOS)*	UG/L	0.01				-	0.02	<0.01	0.18	<0.01	0.13	0.06	0.27	<0.01	<0.01	0.23	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	0.17
	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*	UG/L	0.01				-	0.02	<0.01	0.24	<0.01	0.25	0.11	0.46	<0.01	<0.01	0.24	<0.01	<0.01	<0.01	<0.01	<0.01	0.14	0.19
VFA	4-Methylvaleric acid*	MG/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Heptanoic acid*	MG/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Isovaleric acid*	MG/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Isobutyric acid*	MG/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Total VFA as Acetic Acid Equivalents*	MG/L	5				-	-	-	-	-	-	-	-	-	9.9	11	-	-	-	-	-	-	-
BTEX	Benzene	µg/L	1		**900**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Ethylbenzene	µg/L	1		**110**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Toluene	µg/L	1		**230**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Xylene (m & p)	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Xylene (o)	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Xylene Total	µg/L	3				-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-
	C6-C10 less BTEX (F1)	mg/L	0.02				-	-	-	-	-	-	-	-	-	<0.02	<0.02	-	-	-	-	-	-	-
Chlorinated Hydrocarbo	1,1,1,2-tetrachloroethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,1,1-trichloroethane	µg/L	1		**400**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-

Field ID	GW SUMP	GW12-12	GW12-30	GW13-12	GW14-12	GW14-3	GW16-12	GW16-3	GW16-30	GW17-30	GW18-12	GW2-12	GW2-3	GW3-12	GW4-30	GW5-12	GW5-3	GW7-12
Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	9/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021
LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043
Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER

Chemical Group	Chemical Name	Units	EQL	Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
	1,1,2,2-tetrachloroethane	µg/L	1		**500**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,1,2-trichloroethane	µg/L	1		**5800**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,1-dichloroethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,1-dichloroethene	µg/L	1		**900**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,2,3-trichloropropane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,2-dichloroethane	µg/L	1		**2600**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,2-dichloropropane	µg/L	1		**1200**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,3-dichloropropane	µg/L	1		**1400**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Bromochloromethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Bromodichloromethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Bromoform	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Carbon tetrachloride	µg/L	1		**320**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Chlorodibromomethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Chloroethane	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Chloroform	µg/L	5		**1100**		-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Chloromethane	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	cis-1,2-dichloroethene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	cis-1,3-dichloropropene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Dibromomethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Dichloromethane	µg/L	5		**5000**		-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Trichloroethene	µg/L	1		**400**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Tetrachloroethene	µg/L	1		**100**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	trans-1,2-dichloroethene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	trans-1,3-dichloropropene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Vinyl chloride	µg/L	5		**140**		-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
Explosives	1,3,5-Trinitrobenzene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,3-Dinitrobenzene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2,4,6-Trinitrotoluene (TNT)	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2,4-& 2,6-Dinitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2-Nitrotoluene	µg/L	100				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4-Nitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	m-Nitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nitrobenzene	µg/L	100				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RDX	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Halogenated Benzenes	1,2-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,3-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	1,4-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	4-chlorotoluene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Bromobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Chlorobenzene	µg/L	1		**100**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Hexachlorobenzene	µg/L	0.2		**0.2**		-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
Halogenated Hydrocarbo	1,2-dibromoethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Bromomethane	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Dichlorodifluoromethane	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Iodomethane	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Trichlorofluoromethane	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
Halogenated Phenols	2,4,5-trichlorophenol	µg/L	10				-	-	-	-	-	-	-	-	-	<10	<10	-	-	-	-	-	-	-
	2,4,6-trichlorophenol	µg/L	10				-	-	-	-	-	-	-	-	-	<10	<10	-	-	-	-	-	-	-
	2,4-dichlorophenol	µg/L	3				-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-
	2,6-dichlorophenol	µg/L	3				-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-
	2-chlorophenol	µg/L	3				-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-
	Pentachlorophenol	µg/L	10		**33**		-	-	-	-	-	-	-	-	-	<10	<10	-	-	-	-	-	-	-
	tetrachlorophenols	µg/L	30				-	-	-	-	-	-	-	-	-	<30	<30	-	-	-	-	-	-	-
Herbicides	2,4,5-Trichlorophenoxy-propanoic acid	mg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Dinoseb	µg/L	100				-	-	-	-	-	-	-	-	-	<100	<100	-	-	-	-	-	-	-
	Glyphosate	mg/L	0.01				-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-
Inorganics	Alkalinity (Bicarbonate as CaCO3)	mg/L	20				<20	<20	<20	22	23	<20	<20	<20	<20	45	<20	230	<20	<20	<20	93	51	140
	Carbonate Alkalinity (as CaCO3)	MG/L	10				<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	27	<10	<10	<10	<10	<10	<10	<10
	Nitrite + Nitrate as N	mg/L	0.05				8.1	0.96	0.24	<0.05	0.64	3.3	0.55	11	0.18	0.88	12	22	4.4	0.43	0.22	0.11	3.7	0.12

				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%	Field ID	GW SUMP	GW12-12	GW12-30	GW13-12	GW14-12	GW14-3	GW16-12	GW16-3	GW16-30	GW17-30	GW18-12	GW2-12	GW2-3	GW3-12	GW4-30	GW5-12	GW5-3	GW7-12
							Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	9/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021
							LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043
							Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
Chemical Group	Chemical Name	Units	EQL																						
	Alkalinity (Hydroxide) as CaCO3	µg/L	20000				<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000
	Alkalinity (total) as CaCO3	mg/L	20				<20	<20	<20	22	23	<20	<20	<20	<20	45	43	230	<20	<20	<20	93	51	140	
	Ammonia as N	µg/L	10	**20**	**1200**		**1800**	20	20	**2000**	20	30	20	**1200**	60	20	80	**66,000**	20	90	10	<10	20	130	
	Chloride	mg/L	1				150	34	6.8	61	5500	960	53	110	19	14,000	200	7400	480	140	310	780	1100	2600	
	COD	mg/L	25				190	<25	<25	<25	74	54	<25	<25	<25	310	77	190	<25	<25	<25	<25	120	28	
	Kjeldahl Nitrogen Total	mg/L	0.2				8.8	0.3	0.4	2.2	<0.2	1.1	0.3	3.2	0.5	<0.2	1	66	1	0.6	0.6	<0.2	1.4	0.6	
	Nitrate (as N)	mg/L	0.02				8.1	0.96	0.24	<0.02	0.64	3.3	0.55	11	0.18	0.16	10	14	4.4	0.43	0.22	0.1	3.7	0.1	
	Nitrite (as N)	mg/L	0.02				<0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.72	1	8.2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	
	Nitrogen (Total)	µg/L	200	**300**			**16,900**	1260	640	2200	640	4400	850	14,200	680	880	13,000	40,000	5400	1030	820	<200	5100	720	
	Reactive Phosphorus as P	µg/L	0.01	**10**			1.4	0.13	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.4	0.04	0.01	0.07	0.07	0.01	0.06	
	Sodium	mg/L	0.5				46	18	2.6	34	3100	5400	35	74	22	6500	200	3700	240	88	170	470	590	1400	
	Sulphate	mg/L	5				220	69	<5	<5	640	200	<5	23	20	1100	210	1000	38	19	34	120	160	390	
	TDS	mg/L	10				880	100	120	150	6700	1800	130	250	130	16,000	790	9900	900	280	520	1400	2100	4100	
	TOC	mg/L	5				56	<5	<5	<5	<5	<5	<5	<5	<5	<5	8	<5	<5	<5	<5	<5	<5	<5	
	TSS	mg/L	5	**10**			**140**	85	9.9	19	<5	16	6.1	110	5.5	8.7	120	6.5	5.2	5.6	<5	<5	49	<5	
Lead	Lead	mg/L	0.001		**0.0066**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Lead (Filtered)	mg/L	0.001		**0.0066**		0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
MAH	1,2,4-trimethylbenzene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-	
	1,3,5-trimethylbenzene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-	
	Total MAH	mg/L	0.003				-	-	-	-	-	-	-	-	-	<0.003	<0.003	-	-	-	-	-	-	-	
	Isopropylbenzene	µg/L	1		**40**		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-	
	Styrene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-	
Metals	Aluminium	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Arsenic	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Arsenic (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	<0.001	0.001	-	-	-	-	-	-	-	
	Barium	mg/L	0.02				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Barium (Filtered)	mg/L	0.02				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Beryllium	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Beryllium (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	<0.001	<0.001	-	-	-	-	-	-	-	
	Boron	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Boron (Filtered)	mg/L	0.05				0.2	0.09	<0.05	0.08	0.72	<0.5	<0.05	0.15	<0.05	0.31	0.13	0.47	0.06	<0.05	<0.05	0.86	0.59	1.5	
	Cadmium	mg/L	0.0002		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Cadmium (Filtered)	mg/L	0.0002		**0.014**		-	-	-	-	-	-	-	-	-	0.0004	<0.0002	-	-	-	-	-	-	-	
	Calcium	mg/L	0.5				42	5.9	1.6	4.9	170	760	2.8	9.2	3	1600	71	340	27	10	12	11	36	30	
	Chromium (hexavalent)	mg/L	0.005		**0.02**		-	-	-	-	-	-	-	-	-	<0.005	<0.005	-	-	-	-	-	-	-	
	Chromium (III+VI)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Chromium (III+VI) (Filtered)	mg/L	0.001				0.001	<0.001	<0.001	<0.001	0.028	<0.001	<0.001	<0.001	<0.001	-	-	<0.001	<0.001	<0.001	0.002	0.004	<0.001	<0.001	
	Cobalt	mg/L	0.001		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Cobalt (Filtered)	mg/L	0.001		**0.014**		-	-	-	-	-	-	-	-	-	0.004	0.001	-	-	-	-	-	-	-	
	Copper	mg/L	0.001		**0.003**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Copper (Filtered)	mg/L	0.001		**0.003**		**0.007**	**0.003**	<0.001	<0.001	**0.005**	0.002	<0.001	0.002	<0.001	<0.001	**0.004**	0.002	<0.001	0.002	<0.001	<0.001	0.001	<0.001	
	Iron	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Iron (Filtered)	mg/L	0.05				-	-	-	-	-	-	-	-	-	<0.05	<0.05	-	-	-	-	-	-	-	
	Lithium	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Magnesium	mg/L	0.5				22	1.1	1.3	1.1	250	720	<0.5	4.1	1.1	740	24	420	25	7.9	11	21	44	67	
	Manganese	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Manganese (Filtered)	mg/L	0.005				-	-	-	-	-	-	-	-	-	0.76	0.005	-	-	-	-	-	-	-	
	Mercury	mg/L	0.0001		**0.0007**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Mercury (Filtered)	mg/L	0.0001		**0.0007**		-	-	-	-	-	-	-	-	-	<0.0001	<0.0001	-	-	-	-	-	-	-	
	Nickel	mg/L	0.001		**0.2**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Nickel (Filtered)	mg/L	0.001		**0.2**		0.002	0.002	0.001	0.003	0.051	0.013	<0.001	0.002	0.003	0.024	0.002	0.066	0.004	0.006	0.004	<0.001	0.008	0.005	
	Phosphorus	mg/L	0.01				2	0.03	0.04	0.02	0.01	<0.01	0.01	0.02	0.02	0.02	0.41	0.89	<0.01	0.02	0.16	0.06	<0.01	0.07	
	Potassium	mg/L	0.5				100	2.1	0.8	6.4	68	190	<0.5	11	3.7	120	65	63	4.4	2.7	6.5	26	41	56	
	Selenium	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Selenium (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	<0.001	<0.001	-	-	-	-	-	-	-	
	Tin	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Vanadium	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Vanadium (Filtered)	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	<0.005	0.025	-	-	-	-	-	-	-	
	Zinc	mg/L	0.005		**0.023**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

						Field ID	GW SUMP	GW12-12	GW12-30	GW13-12	GW14-12	GW14-3	GW16-12	GW16-3	GW16-30	GW17-30	GW18-12	GW2-12	GW2-3	GW3-12	GW4-30	GW5-12	GW5-3	GW7-12
						Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	9/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021
						LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																			
Chemical Group	Chemical Name	Units	EQL																					
	Zinc (Filtered)	mg/L	0.005		**0.023**		**0.039**	**0.043**	0.022	**0.035**	**0.11**	**0.026**	0.02	**0.094**	**0.023**	<0.005	<0.005	**0.43**	**0.033**	**0.12**	**0.074**	0.018	**0.023**	**0.039**
Organochlorine Pesticide	4,4-DDE	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	a-BHC	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Aldrin	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Aldrin + Dieldrin	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	b-BHC	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	chlordane	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	d-BHC	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	DDD	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	DDT	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	DDT+DDE+DDD	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Dieldrin	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Endosulfan I	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Endosulfan II	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Endosulfan sulphate	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Endrin	µg/L	0.2		**0.01**		-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Endrin aldehyde	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Endrin ketone	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	g-BHC (Lindane)	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Heptachlor	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Heptachlor epoxide	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Methoxychlor	µg/L	0.2				-	-	-	-	-	-	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-
	Toxaphene	mg/L	0.005				-	-	-	-	-	-	-	-	-	<0.005	<0.005	-	-	-	-	-	-	-
Organophosphorous Pe	Azinophos methyl	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Bolstar (Sulprofos)	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Chlorfenvinphos	µg/L	20				-	-	-	-	-	-	-	-	-	<20	<20	-	-	-	-	-	-	-
	Chlorpyrifos	µg/L	2		**0.04**		-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Chlorpyrifos-methyl	mg/L	0.002				-	-	-	-	-	-	-	-	-	<0.002	<0.002	-	-	-	-	-	-	-
	Coumaphos	µg/L	20				-	-	-	-	-	-	-	-	-	<20	<20	-	-	-	-	-	-	-
	Demeton-O	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Demeton-S	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Diazinon	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Dichlorvos	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Dimethoate	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Disulfoton	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Ethion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Ethoprop	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Fenitrothion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Fensulfothion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Fenthion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Malathion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Merphos	mg/L	0.002				-	-	-	-	-	-	-	-	-	<0.002	<0.002	-	-	-	-	-	-	-
	Methyl parathion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Mevinphos (Phosdrin)	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Monocrotophos	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Naled (Dibrom)	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Omethoate	µg/L	20				-	-	-	-	-	-	-	-	-	<20	<20	-	-	-	-	-	-	-
	Phorate	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Pyrazophos	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Ronnel	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Terbufos	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Trichloronate	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Tetrachlorvinphos	mg/L	0.002				-	-	-	-	-	-	-	-	-	<0.002	<0.002	-	-	-	-	-	-	-
Organotins	Tributyltin	µg/L	12.5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	Butyric Acid	mg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Hexanoic Acid	mg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	6:2 Fluorotelomer Sulfonate (6:2 FtS)	mg/L	0.00005				-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
PAH	Benzo(b+j)fluoranthene	mg/L	0.001				-	-	-	-	-	-	-	-	-	<0.001	<0.001	-	-	-	-	-	-	-
PAH/Phenols	2,4-dimethylphenol	µg/L	3				-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-

				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
	Field ID						GW SUMP	GW12-12	GW12-30	GW13-12	GW14-12	GW14-3	GW16-12	GW16-3	GW16-30	GW17-30	GW18-12	GW2-12	GW2-3	GW3-12	GW4-30	GW5-12	GW5-3	GW7-12
	Sampled Date						10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	9/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021
	LabReport Number						840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043	840043
	Matrix_Type						WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
Chemical Group	Chemical Name	Units	EQL																				
	2,4-dinitrophenol	mg/L	0.03				-	-	-	-	-	-	-	-	-	<0.03	<0.03	-	-	-	-	-	-	-
	2-methylphenol	µg/L	3				-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-
	2-nitrophenol	µg/L	10				-	-	-	-	-	-	-	-	-	<10	<10	-	-	-	-	-	-	-
	3-&4-methylphenol	µg/L	6				-	-	-	-	-	-	-	-	-	<6	<6	-	-	-	-	-	-	-
	4,6-Dinitro-2-methylphenol	µg/L	30				-	-	-	-	-	-	-	-	-	<30	<30	-	-	-	-	-	-	-
	4-chloro-3-methylphenol	µg/L	10				-	-	-	-	-	-	-	-	-	<10	<10	-	-	-	-	-	-	-
	4-nitrophenol	µg/L	30				-	-	-	-	-	-	-	-	-	<30	<30	-	-	-	-	-	-	-
	Acenaphthene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Acenaphthylene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Anthracene	µg/L	1		1.5		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Benz(a)anthracene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Benzo(a) pyrene	µg/L	1		0.4		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Benzo(g,h,i)perylene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Benzo(k)fluoranthene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Chrysene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Cresol Total	mg/L	0.01				-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-
	Dibenz(a,h)anthracene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Fluoranthene	µg/L	1		1.7		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Fluorene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Indeno(1,2,3-c,d)pyrene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Naphthalene	µg/L	1		90		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	PAHs (Sum of total)	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Phenanthrene	µg/L	1		4		-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
	Phenol	µg/L	3		520		-	-	-	-	-	-	-	-	-	<3	<3	-	-	-	-	-	-	-
	Pyrene	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
Pesticides	Parathion	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
	Pirimiphos-methyl	mg/L	0.02				-	-	-	-	-	-	-	-	-	<0.02	<0.02	-	-	-	-	-	-	-
Phenolics	4,6-Dinitro-o-cyclohexyl phenol	µg/L	100				-	-	-	-	-	-	-	-	-	<100	<100	-	-	-	-	-	-	-
	Phenols (Total Halogenated)	mg/L	0.01				-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-
	Phenols (Total Non Halogenated)	mg/L	0.1				-	-	-	-	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	-	-
Polychlorinated Biphenyl	Arochlor 1016	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Arochlor 1221	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Arochlor 1232	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Arochlor 1242	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Arochlor 1248	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Arochlor 1254	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Arochlor 1260	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	PCBs (Sum of total)	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
Solvents	Methyl Ethyl Ketone	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	4-Methyl-2-pentanone	µg/L	5				-	-	-	-	-	-	-	-	-	<5	<5	-	-	-	-	-	-	-
	Acetone	mg/L	0.005				-	-	-	-	-	-	-	-	-	<0.005	<0.005	-	-	-	-	-	-	-
	Allyl chloride	mg/L	0.001				-	-	-	-	-	-	-	-	-	<0.001	<0.001	-	-	-	-	-	-	-
	Carbon disulfide	µg/L	1				-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
SVOCs	EPN	µg/L	2				-	-	-	-	-	-	-	-	-	<2	<2	-	-	-	-	-	-	-
TPH	C10-C16	mg/L	0.05				-	-	-	-	-	-	-	-	-	<0.05	<0.05	-	-	-	-	-	-	-
	C16-C34	mg/L	0.1				-	-	-	-	-	-	-	-	-	<0.1	0.2	-	-	-	-	-	-	-
	C34-C40	mg/L	0.1				-	-	-	-	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	-	-
	F2-NAPHTHALENE	mg/L	0.05				-	-	-	-	-	-	-	-	-	<0.05	<0.05	-	-	-	-	-	-	-
	+C10 - C36 (Sum of total)	µg/L	100				-	-	-	-	-	-	-	-	-	<100	200	-	-	-	-	-	-	-
	C6 - C9	µg/L	20				-	-	-	-	-	-	-	-	-	<20	<20	-	-	-	-	-	-	-
	C10 - C14	µg/L	50				-	-	-	-	-	-	-	-	-	<50	<50	-	-	-	-	-	-	-
	C15 - C28	µg/L	100				-	-	-	-	-	-	-	-	-	<100	100	-	-	-	-	-	-	-
	C29-C36	µg/L	100				-	-	-	-	-	-	-	-	-	<100	100	-	-	-	-	-	-	-
	C10 - C40 (Sum of total)	µg/L	100				-	-	-	-	-	-	-	-	-	<100	200	-	-	-	-	-	-	-
	C6-C10	mg/L	0.02				-	-	-	-	-	-	-	-	-	<0.02	<0.02	-	-	-	-	-	-	-

							Field ID	GW7-3	GW8-12	GW8-3	LP02	SW12	SW13	WW6	WW9	GW17-12	GW17-30	GW18-12	GW18-3	GWSUMP	SW12	SW13	SW14	DW2	DW3
							Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	12/01/2022	12/01/2022
							LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	849609	849609	849609	849609	849609	849609	849609	849609	856948	856948
							Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																			
Chemical Group	Chemical Name	Units	EQL																						
Field	SWL	mbgl						1.28	2.17	2.57	-	-	-	3.33	2.05	8.99	9.65	6.08	2.21	-	-	-	-	-	-
	pH	pH		6-8.5	6-8			5.91	6.2	4.84	-	6.01	6.01	6.58	5.07	5.27	11.99	7.12	6.14	7.19	7.57	7.43	7.68	7.86	7.69
	Electrical conductivity	uS/cm						2126	8190	4297	-	1124	1583	66319	2558	12923	23832	7046	1750	494.5	1285	1442	1034	2415	147.5
	Redox Potential	mV						138.7	174.2	134.8	-	98.9	100.3	124.7		91.2	-97.5	85.5	118.1	17.5	41.2	55.3	67.9	-200.86	41.8
	Dissolved Oxygen	%S		80-100				18.1	31.5	7.6	-	86.6	79.9	21.8	92.4	74.9	88.1	20.7	66.7	28.9	107.5	118.5	8.12	77.6	79.5
	Temp	oC						29.1	28.3	28.4	-	29	27.5	29	30	27.9	27.9	29.1	30.9	28.8	29	26.7	30.1	33.6	35.8
	Turbidity	ntu						170.6	1.12	9.37	-	934.6	1387.1	2.95	3.06	-	-	-	-	333.9	140.2	85.7	15.7	3160.8	1188.7
	Tokuthion	mg/L	0.002					-	-	-	-	-	-	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
	Acetic Acid	µg/L	5000					-	-	-	-	-	-	-	-	<5000	5100	<5000	<5000	-	-	-	-	-	-
	Aminomethyl phosphonic acid	µg/L	10					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Valeric Acid	µg/L	5000					-	-	-	-	-	-	-	-	<5000	<5000	<5000	<5000	-	-	-	-	-	-
PFAS	(N-EtFOSA)	mg/L	0.00005					<0.00005	<0.00005	<0.00005	<0.0001	-	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	-	-	-	<0.00005	<0.00005
	Perfluoronon anesulfonic acid (PFNS) (trace)	µg/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	(8:2 FTSA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.02	<0.01
	(10:2 FTSA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	(4:2 FTSA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.02	<0.01
	(N-EtFOSAA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05
	(N-EtFOSE)	UG/L	0.05					<0.05	<0.05	<0.05	<0.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05
	(N-MeFOSAA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05
	(N-MeFOSE)	UG/L	0.05					<0.05	<0.05	<0.05	<0.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05
	N-methylperfluoro-1-octane sulfonamide (N-MeFOS	UG/L	0.05					<0.05	<0.05	<0.05	<0.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05
	Sum of PFASs (n=30)*	UG/L	0.1					1.31	<0.1	1.24	38.6	-	-	0.23	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	34.04	17.99
	Sum of US EPA PFAS (PFOS + PFOA)*	UG/L	0.01					0.45	0.01	0.44	<2	-	-	0.04	<0.01	<0.01	0.03	0.04	0.04	-	-	-	-	3.1	1.09
	Sum of WA DWER PFAS (n=10)*	UG/L	0.05					1.24	<0.05	1.14	38.6	-	-	0.23	<0.05	<0.05	<0.05	0.09	0.07	-	-	-	-	33.42	17.91
	Perfluorobutanesulfonic acid (PFBS)	UG/L	0.01					0.17	<0.01	0.11	8.7	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	17	6
	Perfluorobutanoic acid (PFBA)	UG/L	0.05					0.18	<0.05	0.15	<10	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	2	1.2
	Perfluorodecanesulfonic acid (PFDS)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	Perfluorodecanoic acid (PFDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.06	0.01
	Perfluorododecanoic acid (PFDoDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	Perfluoroheptanesulfonic acid (PFHpS)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.06	<0.01
	Perfluoroheptanoic acid (PFHpA)	UG/L	0.01					0.06	<0.01	0.05	1.5	-	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.77	0.54
	Perfluorohexanesulfonic acid (PFHxS)	UG/L	0.01					0.16	<0.01	0.21	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	0.05	0.03	-	-	-	-	1.8	0.18
	Perfluorohexanoic acid (PFHxA)	UG/L	0.01					0.11	<0.01	0.1	13	-	-	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	5.6	5.8
	Perfluorononanoic acid (PFNA)	UG/L	0.01					0.02	<0.01	0.02	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.04	0.02
	Perfluorooctane sulfonamide (FOSA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05
	Perfluorooctanoate (PFOA)	UG/L	0.01			632		0.18	<0.01	0.17	1.7	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	1.7	1
	Perfluorooctanesulfonic acid (PFOS)	UG/L	0.01			2		0.27	0.01	0.27	<2	-	-	0.04	<0.01	<0.01	0.03	0.04	0.04	-	-	-	-	1.4	0.09
	Perfluoropentanesulfonic acid (PFPeS)	UG/L	0.01					0.02	<0.01	0.04	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.24	0.02
	Perfluoropentanoic acid (PFPeA)	UG/L	0.01					0.11	<0.01	0.08	12	-	-	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	2.2	2.8
	Perfluoropropanesulfonic acid (PFPrS)	UG/L	0.01					0.03	<0.01	0.04	<1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	0.2	0.03
	Perfluorotetradecanoic acid (PFTeDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	Perfluorotridecanoic acid (PFTrDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	Perfluoroundecanoic acid (PFUnDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.1	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01
	Sum (PFHxS + PFOS)*	UG/L	0.01					0.43	0.01	0.48	<2	-	-	0.04	<0.01	<0.01	0.03	0.09	0.07	-	-	-	-	3.2	0.27
	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*	UG/L	0.01					0.61	0.01	0.65	<2	-	-	0.04	<0.01	<0.01	0.03	0.09	0.07	-	-	-	-	4.9	1.27
VFA	4-Methylvaleric acid*	MG/L	5					-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Heptanoic acid*	MG/L	5					-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Isovaleric acid*	MG/L	5					-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Isobutyric acid*	MG/L	5					-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Total VFA as Acetic Acid Equivalents*	MG/L	5					-	-	-	-	-	-	-	-	<5	5.1	<5	<5	-	-	-	-	-	-
BTEX	Benzene	µg/L	1		900			-	-	-	380	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<20	<40
	Ethylbenzene	µg/L	1		110			-	-	-	110	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<20	<40
	Toluene	µg/L	1		230			-	-	-	120	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<20	<40
	Xylene (m & p)	µg/L	2					-	-	-	670	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<40	<80
	Xylene (o)	µg/L	1					-	-	-	370	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	36	65
	Xylene Total	µg/L	3					-	-	-	1000	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	36	<120
	C6-C10 less BTEX (F1)	mg/L	0.02					-	-	-	8.4	-	-	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.4	<0.8
Chlorinated Hydrocarbo	1,1,1,2-tetrachloroethane	µg/L	1					-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,1,1-trichloroethane	µg/L	1		400			-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-

						Field ID	GW7-3	GW8-12	GW8-3	LP02	SW12	SW13	WW6	WW9	GW17-12	GW17-30	GW18-12	GW18-3	GWSUMP	SW12	SW13	SW14	DW2	DW3
						Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	12/01/2022	12/01/2022
						LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	849609	849609	849609	849609	849609	849609	849609	849609	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	Chemical Name	Units	EQL																					
	1,1,2,2-tetrachloroethane	µg/L	1		**500**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,1,2-trichloroethane	µg/L	1		**5800**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,1-dichloroethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,1-dichloroethene	µg/L	1		**900**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,2,3-trichloropropane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,2-dichloroethane	µg/L	1		**2600**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,2-dichloropropane	µg/L	1		**1200**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,3-dichloropropane	µg/L	1		**1400**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Bromochloromethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Bromodichloromethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Bromoform	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Carbon tetrachloride	µg/L	1		**320**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Chlorodibromomethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Chloroethane	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Chloroform	µg/L	5		**1100**		-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Chloromethane	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	cis-1,2-dichloroethene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	cis-1,3-dichloropropene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Dibromomethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Dichloromethane	µg/L	5		**5000**		-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Trichloroethene	µg/L	1		**400**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Tetrachloroethene	µg/L	1		**100**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	trans-1,2-dichloroethene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	trans-1,3-dichloropropene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Vinyl chloride	µg/L	5		**140**		-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
Explosives	1,3,5-Trinitrobenzene	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
	1,3-Dinitrobenzene	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
	2,4,6-Trinitrotoluene (TNT)	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
	2,4-& 2,6-Dinitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
	2-Nitrotoluene	µg/L	100				-	-	-	-	-	-	-	-	<100	<100	<100	<100	-	-	-	-	-	-
	4-Nitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
	m-Nitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
	Nitrobenzene	µg/L	100				-	-	-	-	-	-	-	-	<100	<100	<100	<100	-	-	-	-	-	-
	RDX	mg/L	0.1				-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
Halogenated Benzenes	1,2-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,3-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,4-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	4-chlorotoluene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Bromobenzene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Chlorobenzene	µg/L	1		**100**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Hexachlorobenzene	µg/L	0.2		**0.2**		-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Halogenated Hydrocarbo	1,2-dibromoethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Bromomethane	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Dichlorodifluoromethane	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Iodomethane	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Trichlorofluoromethane	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
Halogenated Phenols	2,4,5-trichlorophenol	µg/L	10				-	-	-	<10	-	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	-	-
	2,4,6-trichlorophenol	µg/L	10				-	-	-	<10	-	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	-	-
	2,4-dichlorophenol	µg/L	3				-	-	-	<3	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	-	-
	2,6-dichlorophenol	µg/L	3				-	-	-	<3	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	-	-
	2-chlorophenol	µg/L	3				-	-	-	<3	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	-	-
	Pentachlorophenol	µg/L	10		**33**		-	-	-	<10	-	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	-	-
	tetrachlorophenols	µg/L	30				-	-	-	<30	-	-	-	-	<30	<30	<30	<30	<30	<30	<30	<30	-	-
Herbicides	2,4,5-Trichlorophenoxy-propanoic acid	mg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Dinoseb	µg/L	100				-	-	-	<100	-	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	-	-
	Glyphosate	mg/L	0.01				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inorganics	Alkalinity (Bicarbonate as CaCO3)	mg/L	20				<20	260	68	7600	44	32	27	<20	<20	<20	110	73	120	75	32	<20	7400	3400
	Carbonate Alkalinity (as CaCO3)	MG/L	10				<10	<10	<10	1400	<10	<10	<10	<10	<10	320	<10	<10	<10	<10	<10	<10	190	<10
	Nitrite + Nitrate as N	mg/L	0.05				37	3.8	220	<5	7.2	5	5	1.1	0.2	0.16	9.7	3.5	<0.05	3.8	5.7	4	<2.5	<2.5

						Field ID	GW7-3	GW8-12	GW8-3	LP02	SW12	SW13	WW6	WW9	GW17-12	GW17-30	GW18-12	GW18-3	GWSUMP	SW12	SW13	SW14	DW2	DW3
						Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	12/01/2022	12/01/2022
						LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	849609	849609	849609	849609	849609	849609	849609	849609	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
Chemical Group	Chemical Name	Units	EQL	Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
	Alkalinity (Hydroxide) as CaCO3	µg/L	20000				<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	1,100,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000
	Alkalinity (total) as CaCO3	mg/L	20				<20	260	68	9000	44	32	27	<20	<20	1400	110	73	120	75	32	<20	7600	3400
	Ammonia as N	µg/L	10	**20**	**1200**		1100	50	**8000**	**810,000**	**1300**	1100	**5600**	<10	<10	**1900**	40	20	**2000**	**480**	**2700**	**220**	**2,000,000**	**900,000**
	Chloride	mg/L	1				520	28,000	1600	9900	190	480	22,000	660	4400	7400	1900	590	77	300	380	220	2100	1000
	COD	mg/L	25				59	2300	45	15,000	49	42	620	<25	90	<25	<25	51	75	27	88	<25	4700	1900
	Kjeldahl Nitrogen Total	mg/L	0.2				23	0.4	11	1100	4.9	5.8	5.6	0.5	<0.2	1.2	<0.2	<0.2	2.3	1.5	1.7	0.8	2000	1100
	Nitrate (as N)	mg/L	0.02				37	3.8	220	<5	7.1	5	4.8	1.1	0.19	0.08	9.2	3.5	<0.02	3.7	5.5	3.6	<1	<2.5
	Nitrite (as N)	mg/L	0.02				0.72	<0.02	1.6	2	<0.02	<0.02	0.11	<0.02	<0.02	0.08	0.54	<0.02	<0.02	0.14	0.15	0.4	<1	<1
	Nitrogen (Total)	µg/L	200	**300**			60,000	4200	231,000	1,100,000	**12,100**	**10,800**	5000	1600	200	1360	9700	3500	**2300**	**5300**	**7400**	**4800**	2,000,000	1,100,000
	Reactive Phosphorus as P	µg/L	0.01	**10**			0.01	0.05	0.06	0.87	<0.01	<0.01	0.9	<0.01	0.03	0.01	0.04	0.02	0.55	0.07	0.01	0.02	9.5	3.5
	Sodium	mg/L	0.5				220	15,000	500	6100	99	210	12,000	310	2100	8400	1900	310	17	120	150	100	2200	850
	Sulphate	mg/L	5				95	3800	180	70	51	70	2700	61	420	110	360	88	12	61	68	73	<50	55
	TDS	mg/L	10				1200	61,000	3900	34,000	1000	1100	46,000	1300	8500	20,000	3400	1100	370	790	930	640	7700	3900
	TOC	mg/L	5				15	11	11	4200	17	12	<5	<5	<5	7.7	<5	<5	24	7.9	8.8	<5	560	1400
	TSS	mg/L	5	**10**			67	10	24	350	**160**	**110**	18	190	200	180	34	8.5	**95**	**36**	**29**	<5	37	64
Lead	Lead	mg/L	0.001		**0.0066**		-	-	-	**0.075**	-	-	-	-	0.005	0.004	0.004	**0.019**	-	-	-	-	**0.016**	**0.014**
	Lead (Filtered)	mg/L	0.001		**0.0066**		<0.001	<0.001	<0.001	-	0.005	0.002	0.003	<0.001	-	-	-	-	<0.001	<0.001	<0.001	<0.001	-	-
MAH	1,2,4-trimethylbenzene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	1,3,5-trimethylbenzene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Total MAH	mg/L	0.003				-	-	-	-	-	-	-	-	<0.003	<0.003	<0.003	<0.003	-	-	-	-	-	-
	Isopropylbenzene	µg/L	1		**40**		-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
	Styrene	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
Metals	Aluminium	mg/L	0.05				-	-	-	1.6	-	-	-	-	-	-	-	-	-	-	-	-	0.89	<0.5
	Arsenic	mg/L	0.001				-	-	-	0.33	-	-	-	-	<0.001	<0.001	<0.001	<0.001	-	-	-	-	0.16	0.035
	Arsenic (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barium	mg/L	0.02				-	-	-	-	-	-	-	-	0.1	0.7	0.1	0.08	-	-	-	-	-	-
	Barium (Filtered)	mg/L	0.02				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryllium	mg/L	0.001				-	-	-	-	-	-	-	-	0.002	<0.001	<0.001	<0.001	-	-	-	-	-	-
	Beryllium (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boron	mg/L	0.05				-	-	-	20	-	-	-	-	0.07	0.32	0.13	0.07	-	-	-	-	4.2	1.4
	Boron (Filtered)	mg/L	0.05				0.31	2.9	1	-	0.08	0.08	0.77	<0.05	-	-	-	-	-	-	-	-	-	-
	Cadmium	mg/L	0.0002		**0.014**		-	-	-	<0.002	-	-	-	-	0.001	0.0005	0.0009	<0.0002	-	-	-	-	<0.002	<0.002
	Cadmium (Filtered)	mg/L	0.0002		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Calcium	mg/L	0.5				42	1000	200	87	34	42	1200	29	310	2100	330	69	12	55	55	57	41	79
	Chromium (hexavalent)	mg/L	0.005		**0.02**		-	-	-	-	-	-	-	-	<0.005	0.006	<0.005	<0.005	-	-	-	-	-	-
	Chromium (III+VI)	mg/L	0.001				-	-	-	1.2	-	-	-	-	-	-	-	-	-	-	-	-	0.49	0.15
	Chromium (III+VI) (Filtered)	mg/L	0.001				<0.001	<0.001	<0.001	-	<0.001	<0.001	0.003	<0.001	-	-	-	-	<0.001	<0.001	<0.001	<0.001	-	-
	Cobalt	mg/L	0.001		**0.014**		-	-	-	**0.2**	-	-	-	-	**0.014**	0.004	0.002	0.003	-	-	-	-	**0.047**	**0.018**
	Cobalt (Filtered)	mg/L	0.001		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Copper	mg/L	0.001		**0.003**		-	-	-	**0.052**	-	-	-	-	0.002	0.002	**0.003**	**0.005**	-	-	-	-	**0.25**	**0.48**
	Copper (Filtered)	mg/L	0.001		**0.003**		**0.005**	0.002	**0.004**	-	**0.011**	**0.007**	**0.004**	**0.004**	-	-	-	-	**0.005**	**0.003**	**0.003**	0.001	-	-
	Iron	mg/L	0.05				-	-	-	18	-	-	-	-	0.17	0.13	0.09	0.36	-	-	-	-	4.2	11
	Iron (Filtered)	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lithium	mg/L	0.005				-	-	-	0.53	-	-	-	-	-	-	-	-	-	-	-	-	0.2	<0.05
	Magnesium	mg/L	0.5				29	1900	94	67	14	29	1600	48	220	1000	210	33	8.4	12	13	9	42	41
	Manganese	mg/L	0.005				-	-	-	0.48	-	-	-	-	0.23	0.94	0.03	0.025	-	-	-	-	0.13	0.31
	Manganese (Filtered)	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mercury	mg/L	0.0001		**0.0007**		-	-	-	<0.0005	-	-	-	-	<0.0001	<0.0001	<0.0001	<0.0001	-	-	-	-	-	-
	Mercury (Filtered)	mg/L	0.0001		**0.0007**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nickel	mg/L	0.001		**0.2**		-	-	-	**0.67**	-	-	-	-	0.11	0.027	0.01	0.004	-	-	-	-	0.16	0.11
	Nickel (Filtered)	mg/L	0.001		**0.2**		0.006	0.025	0.005	-	0.005	0.004	**0.75**	0.016	-	-	-	-	<0.001	0.002	0.003	<0.001	-	-
	Phosphorus	mg/L	0.01				0.03	0.02	0.29	46	0.04	0.02	0.99	0.03	0.1	0.02	0.06	0.08	1	0.02	0.02	0.01	14	9.8
	Potassium	mg/L	0.5				69	500	89	3400	23	24	210	5.6	21	110	43	1.3	51	20	23	8.7	770	390
	Selenium	mg/L	0.001				-	-	-	<0.01	-	-	-	-	<0.001	<0.001	<0.001	<0.001	-	-	-	-	<0.01	<0.01
	Selenium (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tin	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Vanadium	mg/L	0.005		**0.16**		-	-	-	**0.9**	-	-	-	-	<0.005	<0.005	<0.005	0.007	-	-	-	-	**0.27**	0.098
	Vanadium (Filtered)	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Zinc	mg/L	0.005		**0.023**		-	-	-	**2.6**	-	-	-	-	**0.52**	0.005	**0.04**	**0.038**	-	-	-	-	**0.33**	**0.37**

Chemical Group	Chemical Name	Units	EQL	Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%	Field ID	GW7-3	GW8-12	GW8-3	LP02	SW12	SW13	WW6	WW9	GW17-12	GW17-30	GW18-12	GW18-3	GWSUMP	SW12	SW13	SW14	DW2	DW3
							Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	12/01/2022	12/01/2022
							LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	849609	849609	849609	849609	849609	849609	849609	849609	856948	856948
							Matrix_Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
	Zinc (Filtered)	mg/L	0.005		**0.023**			**0.029**	**0.069**	**0.063**	-	**0.039**	0.015	**0.57**	**0.061**	-	-	-	-	0.008	<0.005	<0.005	0.006	-	-
Organochlorine Pesticide	4,4-DDE	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	a-BHC	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Aldrin	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Aldrin + Dieldrin	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	b-BHC	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	chlordane	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	d-BHC	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	DDD	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	DDT	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	DDT+DDE+DDD	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Dieldrin	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Endosulfan I	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Endosulfan II	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Endosulfan sulphate	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Endrin	µg/L	0.2		**0.01**			-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Endrin aldehyde	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Endrin ketone	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	g-BHC (Lindane)	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Heptachlor	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Heptachlor epoxide	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Methoxychlor	µg/L	0.2					-	-	-	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
	Toxaphene	mg/L	0.005					-	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
Organophosphorous Pe	Azinophos methyl	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Bolstar (Sulprofos)	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Chlorfenvinphos	µg/L	20					-	-	-	-	-	-	-	-	<20	<20	<20	<20	<20	<20	<20	<20	-	-
	Chlorpyrifos	µg/L	2		**0.04**			-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Chlorpyrifos-methyl	mg/L	0.002					-	-	-	-	-	-	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
	Coumaphos	µg/L	20					-	-	-	-	-	-	-	-	<20	<20	<20	<20	<20	<20	<20	<20	-	-
	Demeton-O	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Demeton-S	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Diazinon	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Dichlorvos	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Dimethoate	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Disulfoton	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Ethion	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Ethoprop	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Fenitrothion	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Fensulfothion	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Fenthion	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Malathion	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Merphos	mg/L	0.002					-	-	-	-	-	-	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
	Methyl parathion	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Mevinphos (Phosdrin)	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Monocrotophos	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Naled (Dibrom)	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Omethoate	µg/L	20					-	-	-	-	-	-	-	-	<20	<20	<20	<20	<20	<20	<20	<20	-	-
	Phorate	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Pyrazophos	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Ronnel	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Terbufos	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Trichloronate	µg/L	2					-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Tetrachlorvinphos	mg/L	0.002					-	-	-	-	-	-	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
Organotins	Tributyltin	µg/L	12.5					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	Butyric Acid	mg/L	5					-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Hexanoic Acid	mg/L	5					-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	6:2 Fluorotelomer Sulfonate (6:2 FtS)	mg/L	0.00005					<0.00005	<0.00005	<0.00005	0.0017	-	-	0.00013	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	-	-	-	0.00093	0.0003
PAH	Benzo(b+j)fluoranthene	mg/L	0.001					-	-	-	<0.001	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
PAH/Phenols	2,4-dimethylphenol	µg/L	3					-	-	-	<3	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	-	-

							Field ID	GW7-3	GW8-12	GW8-3	LP02	SW12	SW13	WW6	WW9	GW17-12	GW17-30	GW18-12	GW18-3	GWSUMP	SW12	SW13	SW14	DW2	DW3
							Sampled Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	8/12/2021	12/01/2022	12/01/2022
							LabReport Number	840043	840043	840043	840043	840043	840043	840043	840043	849609	849609	849609	849609	849609	849609	849609	849609	856948	856948
							Matrix_Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																				
Chemical Group	**Chemical Name**	**Units**	**EQL**																						
	2,4-dinitrophenol	mg/L	0.03				-	-	-	<0.03	-	-	-	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	-	-
	2-methylphenol	µg/L	3				-	-	-	<3	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	-	-
	2-nitrophenol	µg/L	10				-	-	-	<10	-	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	-	-
	3-&4-methylphenol	µg/L	6				-	-	-	<6	-	-	-	-	<6	<6	<6	<6	<6	<6	<6	<6	-	-
	4,6-Dinitro-2-methylphenol	µg/L	30				-	-	-	<30	-	-	-	-	<30	<30	<30	<30	<30	<30	<30	<30	-	-
	4-chloro-3-methylphenol	µg/L	10				-	-	-	<10	-	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	-	-
	4-nitrophenol	µg/L	30				-	-	-	<30	-	-	-	-	<30	<30	<30	<30	<30	<30	<30	<30	-	-
	Acenaphthene	µg/L	1				-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Acenaphthylene	µg/L	1				-	-	-	4	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Anthracene	µg/L	1		**1.5**		-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Benz(a)anthracene	µg/L	1				-	-	-	2	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Benzo(a) pyrene	µg/L	1		**0.4**		-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Benzo(g,h,i)perylene	µg/L	1				-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Benzo(k)fluoranthene	µg/L	1				-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Chrysene	µg/L	1				-	-	-	2	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Cresol Total	mg/L	0.01				-	-	-	<0.01	-	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
	Dibenz(a,h)anthracene	µg/L	1				-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Fluoranthene	µg/L	1		**1.7**		-	-	-	**4**	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Fluorene	µg/L	1				-	-	-	5	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Indeno(1,2,3-c,d)pyrene	µg/L	1				-	-	-	<1	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Naphthalene	µg/L	1		**90**		-	-	-	**660**	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<200	<400
	PAHs (Sum of total)	µg/L	1				-	-	-	169	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Phenanthrene	µg/L	1		**4**		-	-	-	**4**	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Phenol	µg/L	3		**520**		-	-	-	<3	-	-	-	-	<3	<3	<3	<3	<3	<3	<3	<3	-	-
	Pyrene	µg/L	1				-	-	-	8	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-
Pesticides	Parathion	µg/L	2				-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
	Pirimiphos-methyl	mg/L	0.02				-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-
Phenolics	4,6-Dinitro-o-cyclohexyl phenol	µg/L	100				-	-	-	<100	-	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	-	-
	Phenols (Total Halogenated)	mg/L	0.01				-	-	-	<0.01	-	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
	Phenols (Total Non Halogenated)	mg/L	0.1				-	-	-	<0.1	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Polychlorinated Biphenyl	Arochlor 1016	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Arochlor 1221	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Arochlor 1232	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Arochlor 1242	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Arochlor 1248	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Arochlor 1254	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Arochlor 1260	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	PCBs (Sum of total)	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	-	-
Solvents	Methyl Ethyl Ketone	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	4-Methyl-2-pentanone	µg/L	5				-	-	-	-	-	-	-	-	<5	<5	<5	<5	-	-	-	-	-	-
	Acetone	mg/L	0.005				-	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	-	-	-	-	-	-
	Allyl chloride	mg/L	0.001				-	-	-	-	-	-	-	-	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-
	Carbon disulfide	µg/L	1				-	-	-	-	-	-	-	-	<1	<1	<1	<1	-	-	-	-	-	-
SVOCs	EPN	µg/L	2				-	-	-	-	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	-	-
TPH	C10-C16	mg/L	0.05				-	-	-	4.8	-	-	-	-	<0.05	<0.05	<0.05	0.05	0.14	<0.05	<0.05	<0.05	5.8	2.5
	C16-C34	mg/L	0.1				-	-	-	28	-	-	-	-	<0.1	<0.1	<0.1	0.2	0.9	<0.1	<0.1	<0.1	24	8.8
	C34-C40	mg/L	0.1				-	-	-	7.4	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.2
	F2-NAPHTHALENE	mg/L	0.05				-	-	-	4.14	-	-	-	-	<0.05	<0.05	<0.05	0.05	0.14	<0.05	<0.05	<0.05	5.8	2.5
	+C10 - C36 (Sum of total)	µg/L	100				-	-	-	37,600	-	-	-	-	<100	<100	<100	200	1010	<100	<100	<100	30,700	11,900
	C6 - C9	µg/L	20				-	-	-	3200	-	-	-	-	<20	<20	<20	<20	<20	<20	<20	<20	<400	<800
	C10 - C14	µg/L	50				-	-	-	4600	-	-	-	-	<50	<50	<50	<50	110	<50	<50	<50	5900	2800
	C15 - C28	µg/L	100				-	-	-	16,000	-	-	-	-	<100	<100	<100	200	800	<100	<100	<100	24,000	8700
	C29-C36	µg/L	100				-	-	-	17,000	-	-	-	-	<100	<100	<100	<100	100	<100	<100	<100	800	400
	C10 - C40 (Sum of total)	µg/L	100				-	-	-	40,200	-	-	-	-	<100	<100	<100	250	1040	<100	<100	<100	30,200	11,500
	C6-C10	mg/L	0.02				-	-	-	10	-	-	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.4	<0.8

							Field ID	GW SUMP	GW10-12	GW10-3	GW1-12	GW11-3	GW12-12	GW12-30	GW12-3	GW13-12	GW13-3	GW1-3	GW15-12	GW16-12	GW16-30	GW16-3	GW17-3	GW17-12	GW17-30
							Sampled Date	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	13/01/2022	13/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022
							LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
							Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																			
Chemical Group	**Chemical Name**	**Units**	**EQL**																				
Field	SWL	mbgl					-	1.8	1.65	1.26	1.65	1.8	1.98	0.98	9.87	8.86	1.2	1.53	1.87	6.89	1.53	1.27	2.27	2.18
	pH	pH		**6-8.5**	**6-8**		7.23	4.23	4.08	12.14	4.5	5.51	4.85	6.08	5.57	5.57	4.79	5.51	6.02	5.35	4.9	7.12	5.89	12.33
	Electrical conductivity	uS/cm					528	63.8	64.7	7404	80.5	121	47.9	1440	391.7	645	1631	7.34	277.6	175.3	522	6.62	6.17	9.971
	Redox Potential	mV					75.9	125.6	140.2	-85.44	113.1	102.4	121.6	101.8	-158.5	-132	73.9	47.7	91.9	107.2	99.6	48.8	60.8	-67.1
	Dissolved Oxygen	%S		**80-100**			**45.8**	83.6	79.2	85.5	60.9	66.2	52.6	7.1	44.2	54.2	82.2	93.7	78.1	58.7	47.1	90.2	83.2	55.3
	Temp	oC					24.4	28.7	29.2	28.8	27.8	28.4	28.9	28.2	28.1	28.4	29.7	27.4	28.8	28.5	29	29	29	28.8
	Turbidity	ntu					933.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tokuthion	mg/L	0.002				-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	-
	Acetic Acid	µg/L	5000				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Aminomethyl phosphonic acid	µg/L	10				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1000	<1000	<1000
	Valeric Acid	µg/L	5000				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS	(N-EtFOSA)	mg/L	0.00005				<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
	Perfluorononanesulfonic acid (PFNS)(trace)	µg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(8:2 FTSA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(10:2 FTSA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(4:2 FTSA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(N-EtFOSAA)	UG/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-EtFOSE)	UG/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-MeFOSAA)	UG/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-MeFOSE)	UG/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	N-methylperfluoro-1-octanesulfonamide (N-MeFOS	UG/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Sum of PFASs (n=30)*	UG/L	0.1				1.07	0.2	<0.1	<0.1	0.39	<0.1	<0.1	0.47	0.6	0.53	<0.1	<0.1	0.36	<0.1	0.34	<0.1	<0.1	<0.1
	Sum of US EPA PFAS (PFOS + PFOA)*	UG/L	0.01				0.07	0.06	0.03	<0.01	0.07	0.02	0.02	0.11	0.14	0.18	<0.01	<0.01	0.09	<0.01	0.08	<0.01	<0.01	<0.01
	Sum of WA DWER PFAS (n=10)*	UG/L	0.05				1.07	0.2	0.08	<0.05	0.36	<0.05	<0.05	0.47	0.6	0.52	<0.05	0.07	0.36	<0.05	0.33	<0.05	<0.05	<0.05
	Perfluorobutanesulfonic acid (PFBS)	UG/L	0.01				0.04	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.01	0.19	0.08	<0.01	<0.01	0.1	<0.01	0.03	<0.01	<0.01	<0.01
	Perfluorobutanoic acid (PFBA)	UG/L	0.05				0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Perfluorodecanesulfonic acid (PFDS)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorodecanoic acid (PFDA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorododecanoic acid (PFDoDA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroheptanesulfonic acid (PFHpS)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroheptanoic acid (PFHpA)	UG/L	0.01				0.03	0.02	<0.01	<0.01	0.03	<0.01	<0.01	0.01	0.02	0.02	<0.01	<0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01
	Perfluorohexanesulfonic acid (PFHxS)	UG/L	0.01				<0.01	0.02	0.02	<0.01	0.07	<0.01	<0.01	0.03	0.06	0.1	<0.01	<0.01	0.05	<0.01	0.07	<0.01	<0.01	<0.01
	Perfluorohexanoic acid (PFHxA)	UG/L	0.01				0.49	0.03	0.01	<0.01	0.06	<0.01	<0.01	0.14	0.08	0.07	<0.01	<0.01	0.03	<0.01	0.05	<0.01	<0.01	<0.01
	Perfluorononanoic acid (PFNA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorooctane sulfonamide (FOSA)	UG/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Perfluorooctanoate (PFOA)	UG/L	0.01			**632**	0.07	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	0.02	0.05	0.05	<0.01	<0.01	0.04	<0.01	0.04	<0.01	<0.01	<0.01
	Perfluorooctanesulfonic acid (PFOS)	UG/L	0.01			**2**	<0.01	0.06	0.03	<0.01	0.05	0.02	0.02	0.09	0.09	0.13	<0.01	<0.01	0.05	<0.01	0.04	<0.01	<0.01	<0.01
	Perfluoropentanesulfonic acid (PFPeS)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
	Perfluoropentanoic acid (PFPeA)	UG/L	0.01				0.38	0.07	0.02	<0.01	0.1	<0.01	<0.01	0.17	0.06	0.07	<0.01	<0.01	0.06	<0.01	0.07	<0.01	<0.01	<0.01
	Perfluoropropanesulfonic acid (PFPrS)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorotetradecanoic acid (PFTeDA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorotridecanoic acid (PFTrDA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroundecanoic acid (PFUnDA)	UG/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Sum (PFHxS + PFOS)*	UG/L	0.01				<0.01	0.08	0.05	<0.01	0.12	0.02	0.02	0.12	0.15	0.23	<0.01	<0.01	0.1	<0.01	0.11	<0.01	<0.01	<0.01
	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*	UG/L	0.01				0.07	0.08	0.05	<0.01	0.14	0.02	0.02	0.14	0.2	0.28	<0.01	<0.01	0.14	<0.01	0.15	<0.01	<0.01	<0.01
VFA	4-Methylvaleric acid*	MG/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Heptanoic acid*	MG/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Isovaleric acid*	MG/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Isobutyric acid*	MG/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total VFA as Acetic Acid Equivalents*	MG/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BTEX	Benzene	µg/L	1		**900**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Ethylbenzene	µg/L	1		**110**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Toluene	µg/L	1		**230**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Xylene (m & p)	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Xylene (o)	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Xylene Total	µg/L	3				-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	C6-C10 less BTEX (F1)	mg/L	0.02				-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-
Chlorinated Hydrocarbo	1,1,1,2-tetrachloroethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,1,1-trichloroethane	µg/L	1		**400**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1

				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																	
	Field ID						GW SUMP	GW10-12	GW10-3	GW1-12	GW11-3	GW12-12	GW12-30	GW12-3	GW13-12	GW13-3	GW1-3	GW15-12	GW16-12	GW16-30	GW16-3	GW17-3	GW17-12	GW17-30
	Sampled Date						12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	13/01/2022	13/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022
	LabReport Number						856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
	Matrix_Type						WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
Chemical Group	Chemical Name	Units	EQL																				
	1,1,2,2-tetrachloroethane	µg/L	1		**500**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,1,2-trichloroethane	µg/L	1		**5800**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,1-dichloroethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,1-dichloroethene	µg/L	1		**900**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,2,3-trichloropropane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,2-dichloroethane	µg/L	1		**2600**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,2-dichloropropane	µg/L	1		**1200**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,3-dichloropropane	µg/L	1		**1400**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Bromochloromethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Bromodichloromethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Bromoform	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Carbon tetrachloride	µg/L	1		**320**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Chlorodibromomethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Chloroethane	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	Chloroform	µg/L	5		**1100**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	Chloromethane	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	cis-1,2-dichloroethene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	cis-1,3-dichloropropene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Dibromomethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Dichloromethane	µg/L	5		**5000**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	Trichloroethene	µg/L	1		**400**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Tetrachloroethene	µg/L	1		**100**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	trans-1,2-dichloroethene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	trans-1,3-dichloropropene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Vinyl chloride	µg/L	5		**140**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
Explosives	1,3,5-Trinitrobenzene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
	1,3-Dinitrobenzene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
	2,4,6-Trinitrotoluene (TNT)	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
	2,4-& 2,6-Dinitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
	2-Nitrotoluene	µg/L	100				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<100	<100	<100
	4-Nitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
	m-Nitrotoluene	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
	Nitrobenzene	µg/L	100				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<100	<100	<100
	RDX	mg/L	0.1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
Halogenated Benzenes	1,2-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,3-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,4-dichlorobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	4-chlorotoluene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Bromobenzene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Chlorobenzene	µg/L	1		**100**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Hexachlorobenzene	µg/L	0.2		**0.2**		-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
Halogenated Hydrocarbo	1,2-dibromoethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Bromomethane	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	Dichlorodifluoromethane	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	Iodomethane	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Trichlorofluoromethane	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
Halogenated Phenols	2,4,5-trichlorophenol	µg/L	10				-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	-	-
	2,4,6-trichlorophenol	µg/L	10				-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	-	-
	2,4-dichlorophenol	µg/L	3				-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	-	-	-
	2,6-dichlorophenol	µg/L	3				-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	-	-	-
	2-chlorophenol	µg/L	3				-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	-	-	-
	Pentachlorophenol	µg/L	10		**33**		-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	-	-
	tetrachlorophenols	µg/L	30				-	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	-	-	-
Herbicides	2,4,5-Trichlorophenoxy-propanoic acid	mg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dinoseb	µg/L	100				-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	-	-	-
	Glyphosate	mg/L	0.01				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
Inorganics	Alkalinity (Bicarbonate as CaCO3)	mg/L	20				110	<20	<20	<20	<20	<20	<20	150	20	<20	<20	28	<20	<20	28	-	-	-
	Carbonate Alkalinity (as CaCO3)	MG/L	10				<10	<10	<10	140	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	-	-
	Nitrite + Nitrate as N	mg/L	0.05				1.1	1	0.42	0.1	0.76	2.4	1.7	0.06	<0.05	<0.05	<0.05	0.27	8.7	0.15	0.73	-	-	-

						Field ID	GW SUMP	GW10-12	GW10-3	GW1-12	GW11-3	GW12-12	GW12-30	GW12-3	GW13-12	GW13-3	GW1-3	GW15-12	GW16-12	GW16-30	GW16-3	GW17-3	GW17-12	GW17-30
						Sampled Date	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	13/01/2022	13/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022
						LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	**Chemical Name**	**Units**	**EQL**																				
	Alkalinity (Hydroxide) as CaCO3	µg/L	20000				<20,000	<20,000	<20,000	1,200,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	-	-	-
	Alkalinity (total) as CaCO3	mg/L	20				110	<20	<20	1300	<20	<20	<20	150	20	<20	<20	28	<20	<20	28	-	-	-
	Ammonia as N	µg/L	10	**20**	**1200**		**770**	<10	10	100	30	<10	<10	790	**3400**	390	10	<10	<10	<10	<10	-	-	-
	Chloride	mg/L	1				92	7.8	13	750	14	15	5.9	310	84	80	290	790	85	21	62	-	-	-
	COD	mg/L	25				110	<25	<25	<25	<25	<25	<25	88	<25	88	<25	<25	<25	<25	<25	160	91	<25
	Kjeldahl Nitrogen Total	mg/L	0.2				5.3	0.6	0.9	1	1.1	1.1	1.7	5.4	2.8	3.9	0.7	1.1	2.3	0.6	0.8	-	-	-
	Nitrate (as N)	mg/L	0.02				0.85	1	0.41	0.08	0.76	2.4	1.7	0.04	<0.02	<0.02	0.02	0.27	8.6	0.15	0.73	-	-	-
	Nitrite (as N)	mg/L	0.02				0.21	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-
	Nitrogen (Total)	µg/L	200	**300**			**6400**	1600	1320	1100	1860	3500	3400	5460	2800	3900	700	1370	11,000	750	1530	-	-	-
	Reactive Phosphorus as P	µg/L	0.01	**10**			0.37	<0.01	<0.01	<0.01	0.01	0.06	0.12	0.02	<0.01	0.49	<0.01	0.02	<0.01	<0.01	<0.01	-	-	-
	Sodium	mg/L	0.5				36	6.8	7.5	310	11	14	5.9	80	45	25	200	410	70	43	39	-	-	-
	Sulphate	mg/L	5				15	<5	<5	29	<5	9.3	<5	33	9	<5	32	120	16	39	<5	-	-	-
	TDS	mg/L	10				730	19	35	3000	33	71	22	440	140	220	640	1700	270	130	150	9700	8400	3100
	TOC	mg/L	5				38	<5	<5	<5	<5	<5	<5	34	<5	15	<5	<5	<5	<5	<5	<5	<5	<5
	TSS	mg/L	5	**10**			**230**	14	22	17	72	<5	<5	37	16	68	29	<5	83	<5	<5	49	14	26
Lead	Lead	mg/L	0.001		**0.0066**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lead (Filtered)	mg/L	0.001		**0.0066**		<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.023**	0.002	0.005
MAH	1,2,4-trimethylbenzene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	1,3,5-trimethylbenzene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Total MAH	mg/L	0.003				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.003	<0.003	<0.003
	Isopropylbenzene	µg/L	1		**40**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
	Styrene	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
Metals	Aluminium	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Arsenic	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Arsenic (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001	<0.001	<0.001
	Barium	mg/L	0.02				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barium (Filtered)	mg/L	0.02				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.09	1.1
	Beryllium	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryllium (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001	<0.001	<0.001
	Boron	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boron (Filtered)	mg/L	0.05				<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Cadmium	mg/L	0.0002		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cadmium (Filtered)	mg/L	0.0002		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0018	0.0008	<0.0002
	Calcium	mg/L	0.5				27	1.4	0.7	420	0.9	3.2	1	55	3	2.5	16	90	5.6	3.2	6.8	-	-	-
	Chromium (hexavalent)	mg/L	0.005		**0.02**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.005	<0.005	<0.005
	Chromium (III+VI)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chromium (III+VI) (Filtered)	mg/L	0.001				<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-
	Cobalt	mg/L	0.001		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cobalt (Filtered)	mg/L	0.001		**0.014**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.017**	0.008	<0.001
	Copper	mg/L	0.001		**0.003**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Copper (Filtered)	mg/L	0.001		**0.003**		**0.005**	<0.001	<0.001	<0.001	<0.001	**0.003**	<0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001	<0.001	<0.001	0.001	0.001	0.002
	Iron	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Iron (Filtered)	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
	Lithium	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnesium	mg/L	0.5				10	<0.5	<0.5	<0.5	0.9	<0.5	0.7	35	1.1	1.9	24	57	2.8	1.6	0.6	-	-	-
	Manganese	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Manganese (Filtered)	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27	0.16	<0.005
	Mercury	mg/L	0.0001		**0.0007**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mercury (Filtered)	mg/L	0.0001		**0.0007**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0001	<0.0001	<0.0001
	Nickel	mg/L	0.001		**0.2**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nickel (Filtered)	mg/L	0.001		**0.2**		0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	0.002	0.001	0.007	0.009	<0.001	0.002	<0.001	0.054	0.087	0.001
	Phosphorus	mg/L	0.01				0.46	0.02	0.01	0.01	0.02	0.07	0.16	0.16	0.01	0.05	0.01	0.03	0.01	0.01	0.02	-	-	-
	Potassium	mg/L	0.5				65	<0.5	<0.5	3.1	0.5	9.7	3.7	150	12	8.8	1	12	11	4.6	0.6	-	-	-
	Selenium	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Selenium (Filtered)	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001	<0.001	<0.001
	Tin	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Vanadium	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Vanadium (Filtered)	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Zinc	mg/L	0.005		**0.023**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

						Field ID	GW SUMP	GW10-12	GW10-3	GW1-12	GW11-3	GW12-12	GW12-30	GW12-3	GW13-12	GW13-3	GW1-3	GW15-12	GW16-12	GW16-30	GW16-3	GW17-3	GW17-12	GW17-30
						Sampled Date	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	13/01/2022	13/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022
						LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	**Chemical Name**	**Units**	**EQL**																				
	Zinc (Filtered)	mg/L	0.005		**0.023**		<0.005	0.01	0.005	<0.005	<0.005	0.009	0.012	0.015	0.006	0.01	**0.037**	**0.035**	0.009	0.012	0.007	**0.21**	**0.42**	<0.005
Organochlorine Pesticide	4,4-DDE	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	a-BHC	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Aldrin	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Aldrin + Dieldrin	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	b-BHC	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	chlordane	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	d-BHC	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	DDD	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	DDT	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	DDT+DDE+DDD	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Dieldrin	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Endosulfan I	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Endosulfan II	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Endosulfan sulphate	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Endrin	µg/L	0.2		**0.01**		-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Endrin aldehyde	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Endrin ketone	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	g-BHC (Lindane)	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Heptachlor	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Heptachlor epoxide	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Methoxychlor	µg/L	0.2				-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
	Toxaphene	mg/L	0.005				-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-	-
Organophosphorous Pe	Azinophos methyl	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Bolstar (Sulprofos)	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Chlorfenvinphos	µg/L	20				-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	-	-	-
	Chlorpyrifos	µg/L	2		**0.04**		-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Chlorpyrifos-methyl	mg/L	0.002				-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	-
	Coumaphos	µg/L	20				-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	-	-	-
	Demeton-O	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Demeton-S	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Diazinon	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Dichlorvos	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Dimethoate	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Disulfoton	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Ethion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Ethoprop	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Fenitrothion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Fensulfothion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Fenthion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Malathion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Merphos	mg/L	0.002				-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	-
	Methyl parathion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Mevinphos (Phosdrin)	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Monocrotophos	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Naled (Dibrom)	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Omethoate	µg/L	20				-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	-	-	-
	Phorate	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Pyrazophos	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Ronnel	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Terbufos	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Trichloronate	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Tetrachlorvinphos	mg/L	0.002				-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	-
Organotins	Tributyltin	µg/L	12.5				<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	-	-	-
Other	Butyric Acid	mg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hexanoic Acid	mg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6:2 Fluorotelomer Sulfonate (6:2 FtS)	mg/L	0.00005				<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00007	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
PAH	Benzo(b+j)fluoranthene	mg/L	0.001				-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-
PAH/Phenols	2,4-dimethylphenol	µg/L	3				-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	-	-	-

				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%	Field ID	GW SUMP	GW10-12	GW10-3	GW1-12	GW11-3	GW12-12	GW12-30	GW12-3	GW13-12	GW13-3	GW1-3	GW15-12	GW16-12	GW16-30	GW16-3	GW17-3	GW17-12	GW17-30
							Sampled Date	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	13/01/2022	13/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022	12/01/2022
							LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
							Matrix_Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
Chemical Group	Chemical Name	Units	EQL																									
	2,4-dinitrophenol	mg/L	0.03				-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	-	-	-
	2-methylphenol	µg/L	3				-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	-	-	-
	2-nitrophenol	µg/L	10				-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	-	-
	3-&4-methylphenol	µg/L	6				-	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	-	-	-
	4,6-Dinitro-2-methylphenol	µg/L	30				-	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	-	-	-
	4-chloro-3-methylphenol	µg/L	10				-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	-	-
	4-nitrophenol	µg/L	30				-	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	-	-	-
	Acenaphthene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Acenaphthylene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Anthracene	µg/L	1		**1.5**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Benz(a)anthracene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Benzo(a) pyrene	µg/L	1		**0.4**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Benzo(g,h,i)perylene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Benzo(k)fluoranthene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Chrysene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Cresol Total	mg/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
	Dibenz(a,h)anthracene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Fluoranthene	µg/L	1		**1.7**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Fluorene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Indeno(1,2,3-c,d)pyrene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Naphthalene	µg/L	1		**90**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	PAHs (Sum of total)	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Phenanthrene	µg/L	1		**4**		-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
	Phenol	µg/L	3		**520**		-	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	-	-	-
	Pyrene	µg/L	1				-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
Pesticides	Parathion	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
	Pirimiphos-methyl	mg/L	0.02				-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-
Phenolics	4,6-Dinitro-o-cyclohexyl phenol	µg/L	100				-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	-	-	-
	Phenols (Total Halogenated)	mg/L	0.01				-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
	Phenols (Total Non Halogenated)	mg/L	0.1				-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
Polychlorinated Biphenyl	Arochlor 1016	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	Arochlor 1221	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	Arochlor 1232	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	Arochlor 1242	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	Arochlor 1248	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	Arochlor 1254	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	Arochlor 1260	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
	PCBs (Sum of total)	µg/L	5				-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-	-
Solvents	Methyl Ethyl Ketone	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	4-Methyl-2-pentanone	µg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	<5
	Acetone	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.005	<0.005	0.007
	Allyl chloride	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001	<0.001	<0.001
	Carbon disulfide	µg/L	1				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
SVOCs	EPN	µg/L	2				-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-	-
TPH	C10-C16	mg/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-
	C16-C34	mg/L	0.1				-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
	C34-C40	mg/L	0.1				-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
	F2-NAPHTHALENE	mg/L	0.05				-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-
	+C10 - C36 (Sum of total)	µg/L	100				-	<100	<100	<100	<100	<100	<100	<100	<100	350	<100	<100	<100	<100	<100	<100	-	-	-
	C6 - C9	µg/L	20				-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	-	-	-
	C10 - C14	µg/L	50				-	<50	<50	<50	<50	<50	<50	<50	<50	50	<50	<50	<50	<50	<50	<50	-	-	-
	C15 - C28	µg/L	100				-	<100	<100	<100	<100	<100	<100	<100	<100	300	<100	<100	<100	<100	<100	<100	-	-	-
	C29-C36	µg/L	100				-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	-	-	-
	C10 - C40 (Sum of total)	µg/L	100				-	<100	<100	<100	<100	<100	<100	<100	<100	390	<100	<100	<100	<100	<100	<100	-	-	-
	C6-C10	mg/L	0.02				-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-

							Field ID	GW18-12	GW18-3	GW2-12	GW2-3	GW3-12	GW3-3	GW8-12	GW8-3	GW9-12	GWILP	LMP02	LP02	SW STG1&2	SW STG5	SW12	SW13	SW14	SW15
							Sampled Date	12/01/2022	12/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	13/01/2022	13/01/2022	13/01/2022	13/01/2022
							LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
							Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																			
Chemical Group	**Chemical Name**	**Units**	**EQL**																					
Field	SWL	mbgl						1.57	1.26	1.43	0.98	2.09	1.69	0.95	0.3	3.39	-	-	-	-	-	-	-	-	-
	pH	pH		**6-8.5**	**6-8**			8.36	6.38	6.66	8.45	7.36	4.35	6.33	6.78	4.74	7.35	7.04	8.01	6.56	7.12	6.96	7.11	7.01	6.97
	Electrical conductivity	uS/cm						170	3.14	22900	2858	446.8	243.6	27157	15190	4.44	10076	4377	7816	6.52	337.6	1027	459.7	269.2	1014
	Redox Potential	mV						48.4	57.2	-	86.2	25.8	127.2	88.1	41.3	138.8	306	-57.3	-163.8	85.4	138.2	1517	26.1	61.1	51.5
	Dissolved Oxygen	%S		**80-100**				24.9	42.1	21.7	83.5	83.8	47.4	62.1	77.6	62.7	**23.6**	48.3	78.5	81.2	**101.9**	97.6	84.6	80.5	84.5
	Temp	oC						31.2	30.5	28.9	28.8	30	29.8	25.5	25.7	29.7	26.7	26.3	29.4	26.3	27.2	28.1	25.7	26.7	25.6
	Turbidity	ntu						-	-	-	-	-	-	-	-	-	30.6	51.83	68.05	39.47	1197.8	631.85	11611.5	339.92	82.83
	Tokuthion	mg/L	0.002					-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	<0.002	-	-	-	-	-	-
	Acetic Acid	µg/L	5000					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Aminomethyl phosphonic acid	µg/L	10					<1000	<1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1000
	Valeric Acid	µg/L	5000					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS	(N-EtFOSA)	mg/L	0.00005					<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
	Perfluorononanesulfonic acid (PFNS)(trace)	µg/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(8:2 FTSA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(10:2 FTSA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(4:2 FTSA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	(N-EtFOSAA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	0.16	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-EtFOSE)	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-MeFOSAA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	(N-MeFOSE)	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	N-methylperfluoro-1-octanesulfonamide (N-MeFOS	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Sum of PFASs (n=30)*	UG/L	0.1					0.2	0.5	<0.1	<0.1	<0.1	0.46	-	<0.1	<0.1	14.72	2.04	20.23	<0.1	0.47	2.6	0.65	<0.1	<0.1
	Sum of US EPA PFAS (PFOS + PFOA)*	UG/L	0.01					0.11	0.24	<0.01	<0.01	<0.01	0.02	-	0.01	<0.01	1.19	0.95	1.99	<0.01	0.03	0.45	0.09	<0.01	0.02
	Sum of WA DWER PFAS (n=10)*	UG/L	0.05					0.2	0.48	<0.05	<0.05	<0.05	0.46	-	<0.05	<0.05	14.55	1.79	19.92	<0.05	0.47	2.55	0.65	<0.05	<0.05
	Perfluorobutanesulfonic acid (PFBS)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	0.19	-	<0.01	<0.01	6.1	0.09	9.9	<0.01	0.16	0.21	0.11	<0.01	<0.01
	Perfluorobutanoic acid (PFBA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	0.06	-	<0.05	<0.05	0.98	0.15	1.4	<0.05	<0.05	0.19	0.07	<0.05	<0.05
	Perfluorodecanesulfonic acid (PFDS)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorodecanoic acid (PFDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.03	<0.01	0.09	<0.01	<0.01	0.03	<0.01	<0.01	<0.01
	Perfluorododecanoic acid (PFDoDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroheptanesulfonic acid (PFHpS)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroheptanoic acid (PFHpA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	0.01	-	<0.01	<0.01	0.34	0.08	0.49	<0.01	0.01	0.21	0.05	<0.01	<0.01
	Perfluorohexanesulfonic acid (PFHxS)	UG/L	0.01					0.09	0.24	<0.01	<0.01	<0.01	0.04	-	<0.01	<0.01	0.32	0.34	0.48	<0.01	<0.01	0.01	<0.01	<0.01	0.02
	Perfluorohexanoic acid (PFHxA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	0.07	-	<0.01	<0.01	2.3	0.13	3.5	<0.01	0.1	0.77	0.14	<0.01	<0.01
	Perfluorononanoic acid (PFNA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.03	0.02	0.06	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
	Perfluorooctane sulfonamide (FOSA)	UG/L	0.05					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Perfluorooctanoate (PFOA)	UG/L	0.01			**632**		<0.01	<0.01	<0.01	<0.01	<0.01	0.02	-	<0.01	<0.01	0.87	0.21	1.3	<0.01	0.02	0.42	0.07	<0.01	<0.01
	Perfluorooctanesulfonic acid (PFOS)	UG/L	0.01			**2**		0.11	0.24	<0.01	<0.01	<0.01	<0.01	-	0.01	<0.01	0.32	0.74	0.69	<0.01	0.01	0.03	0.02	<0.01	0.02
	Perfluoropentanesulfonic acid (PFPeS)	UG/L	0.01					<0.01	0.02	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.06	0.03	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoropentanoic acid (PFPeA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	0.07	-	<0.01	<0.01	1.2	0.05	1.6	<0.01	0.17	0.71	0.19	<0.01	<0.01
	Perfluoropropanesulfonic acid (PFPrS)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.05	0.02	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorotetradecanoic acid (PFTeDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluorotridecanoic acid (PFTrDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Perfluoroundecanoic acid (PFUnDA)	UG/L	0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Sum (PFHxS + PFOS)*	UG/L	0.01					0.2	0.48	<0.01	<0.01	<0.01	0.04	-	0.01	<0.01	0.64	1.08	1.17	<0.01	0.01	0.04	0.02	<0.01	0.04
	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*	UG/L	0.01					0.2	0.48	<0.01	<0.01	<0.01	0.06	-	0.01	<0.01	1.51	1.29	2.47	<0.01	0.03	0.46	0.09	<0.01	0.04
VFA	4-Methylvaleric acid*	MG/L	5					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Heptanoic acid*	MG/L	5					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Isovaleric acid*	MG/L	5					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Isobutyric acid*	MG/L	5					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total VFA as Acetic Acid Equivalents*	MG/L	5					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BTEX	Benzene	µg/L	1		**900**			<1	<1	<1	<1	<1	<1	<1	<1	<1	-	<1	<40	-	-	-	-	-	<1
	Ethylbenzene	µg/L	1		**110**			<1	<1	<1	<1	<1	<1	<1	<1	<1	-	2	<40	-	-	-	-	-	<1
	Toluene	µg/L	1		**230**			<1	<1	<1	<1	<1	<1	<1	<1	<1	-	<1	<40	-	-	-	-	-	<1
	Xylene (m & p)	µg/L	2					<2	<2	<2	<2	<2	<2	<2	<2	<2	-	<2	<80	-	-	-	-	-	<2
	Xylene (o)	µg/L	1					<1	<1	<1	<1	<1	<1	<1	<1	<1	-	<1	<40	-	-	-	-	-	<1
	Xylene Total	µg/L	3					<3	<3	<3	<3	<3	<3	<3	<3	<3	-	<3	<120	-	-	-	-	-	<3
	C6-C10 less BTEX (F1)	mg/L	0.02					-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.8	-	-	-	-	-	-
Chlorinated Hydrocarbo	1,1,1,2-tetrachloroethane	µg/L	1					<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,1,1-trichloroethane	µg/L	1		**400**			<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1

						Field ID	GW18-12	GW18-3	GW2-12	GW2-3	GW3-12	GW3-3	GW8-12	GW8-3	GW9-12	GWILP	LMP02	LP02	SW STG1 &2	SW STG5	SW12	SW13	SW14	SW15
						Sampled Date	12/01/2022	12/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	13/01/2022	13/01/2022	13/01/2022	13/01/2022
						LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	Chemical Name	Units	EQL																					
	1,1,2,2-tetrachloroethane	µg/L	1		500		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,1,2-trichloroethane	µg/L	1		5800		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,1-dichloroethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,1-dichloroethene	µg/L	1		900		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,2,3-trichloropropane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,2-dichloroethane	µg/L	1		2600		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,2-dichloropropane	µg/L	1		1200		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,3-dichloropropane	µg/L	1		1400		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Bromochloromethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Bromodichloromethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Bromoform	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Carbon tetrachloride	µg/L	1		320		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Chlorodibromomethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Chloroethane	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	Chloroform	µg/L	5		1100		<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	Chloromethane	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	cis-1,2-dichloroethene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	cis-1,3-dichloropropene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Dibromomethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Dichloromethane	µg/L	5		5000		<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	Trichloroethene	µg/L	1		400		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Tetrachloroethene	µg/L	1		100		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	trans-1,2-dichloroethene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	trans-1,3-dichloropropene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Vinyl chloride	µg/L	5		140		<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
Explosives	1,3,5-Trinitrobenzene	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
	1,3-Dinitrobenzene	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
	2,4,6-Trinitrotoluene (TNT)	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
	2,4-& 2,6-Dinitrotoluene	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
	2-Nitrotoluene	µg/L	100				<100	<100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<100
	4-Nitrotoluene	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
	m-Nitrotoluene	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
	Nitrobenzene	µg/L	100				<100	<100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<100
	RDX	mg/L	0.1				<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
Halogenated Benzenes	1,2-dichlorobenzene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,3-dichlorobenzene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,4-dichlorobenzene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	4-chlorotoluene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Bromobenzene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Chlorobenzene	µg/L	1		100		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Hexachlorobenzene	µg/L	0.2		0.2		-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
Halogenated Hydrocarbo	1,2-dibromoethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Bromomethane	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	Dichlorodifluoromethane	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	Iodomethane	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Trichlorofluoromethane	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
Halogenated Phenols	2,4,5-trichlorophenol	µg/L	10				-	-	<10	<10	<10	<10	<10	<10	<10	-	-	-	-	-	-	-	-	-
	2,4,6-trichlorophenol	µg/L	10				-	-	<10	<10	<10	<10	<10	<10	<10	-	-	-	-	-	-	-	-	-
	2,4-dichlorophenol	µg/L	3				-	-	<3	<3	<3	<3	<3	<3	<3	-	-	-	-	-	-	-	-	-
	2,6-dichlorophenol	µg/L	3				-	-	<3	<3	<3	<3	<3	<3	<3	-	-	-	-	-	-	-	-	-
	2-chlorophenol	µg/L	3				-	-	<3	<3	<3	<3	<3	<3	<3	-	-	-	-	-	-	-	-	-
	Pentachlorophenol	µg/L	10		33		-	-	<10	<10	<10	<10	<10	<10	<10	-	-	-	-	-	-	-	-	-
	tetrachlorophenols	µg/L	30				-	-	<30	<30	<30	<30	<30	<30	<30	-	-	-	-	-	-	-	-	-
Herbicides	2,4,5-Trichlorophenoxy-propanoic acid	mg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dinoseb	µg/L	100				-	-	<100	<100	<100	<100	<100	<100	<100	-	-	-	-	-	-	-	-	-
	Glyphosate	mg/L	0.01				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
Inorganics	Alkalinity (Bicarbonate as CaCO3)	mg/L	20				-	-	47	<20	<20	<20	100	220	<20	3100	650	5500	54	32	36	<20	<20	-
	Carbonate Alkalinity (as CaCO3)	MG/L	10				-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	81	<10	<10	<10	<10	<10	-
	Nitrite + Nitrate as N	mg/L	0.05				-	-	2.3	2.7	2.2	8.2	40	3.6	0.23	<2.5	0.15	<2.5	0.31	0.56	1.2	1.7	0.43	-

						Field ID	GW18-12	GW18-3	GW2-12	GW2-3	GW3-12	GW3-3	GW8-12	GW8-3	GW9-12	GWILP	LMP02	LP02	SW STG1&2	SW STG5	SW12	SW13	SW14	SW15
						Sampled Date	12/01/2022	12/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	13/01/2022	13/01/2022	13/01/2022	13/01/2022
						LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	Chemical Name	Units	EQL																					
	Alkalinity (Hydroxide) as CaCO3	µg/L	20000				-	-	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	<20,000	-
	Alkalinity (total) as CaCO3	mg/L	20				-	-	47	<20	<20	<20	100	220	<20	3100	650	5600	54	32	36	<20	<20	-
	Ammonia as N	µg/L	10	**20**	**1200**		-	-	140	<10	<10	20	**6000**	<10	<10	**770,000**	**110,000**	**1,500,000**	**110**	**270**	**210**	**210**	**40**	-
	Chloride	mg/L	1				-	-	6300	720	110	41	9800	31,000	5.7	1200	150	1900	15	73	190	110	56	-
	COD	mg/L	25				<25	<25	350	<25	<25	<25	-	230	<25	1800	120	3000	<25	35	66	49	42	<25
	Kjeldahl Nitrogen Total	mg/L	0.2				-	-	1.8	1.9	0.4	5.1	8.6	0.6	1	730	86	1600	1.3	1.7	2.3	2.4	1.2	-
	Nitrate (as N)	mg/L	0.02				-	-	2.2	2.6	2.2	8.1	36	3.6	0.23	<2.5	0.13	<1	0.29	0.38	1.1	1.6	0.42	-
	Nitrite (as N)	mg/L	0.02				-	-	0.13	<0.02	<0.02	<0.02	4.3	<0.02	<0.02	<1	<0.02	<1	<0.02	0.18	0.13	0.13	<0.02	-
	Nitrogen (Total)	µg/L	200	**300**			-	-	4100	4600	2600	13,300	48,600	4200	1230	**730,000**	86,150	1,600,000	**1610**	**2260**	**3500**	**4100**	**1630**	-
	Reactive Phosphorus as P	µg/L	0.01	**10**			-	-	0.64	<0.01	0.17	0.03	0.19	0.02	0.02	2.8	<0.01	8.2	<0.01	<0.01	0.01	<0.01	<0.01	-
	Sodium	mg/L	0.5				-	-	3800	440	63	42	5200	17,000	7.8	1100	160	1500	16	53	100	67	32	-
	Sulphate	mg/L	5				-	-	990	60	20	6	1300	3700	<5	29	10	<5	26	32	65	59	36	-
	TDS	mg/L	10				550	850	15,000	1400	250	140	-	46,000	34	3900	700	6400	140	410	610	700	260	620
	TOC	mg/L	5				<5	<5	<5	<5	<5	<5	-	<5	<5	780	58	1200	<5	6.8	16	12	6.7	<5
	TSS	mg/L	5	**10**			6.5	270	<5	22	<5	32	-	<5	16	33	70	55	**12**	**480**	**140**	**370**	**130**	**15**
Lead	Lead	mg/L	0.001		**0.0066**		-	-	-	-	-	-	-	<0.001	-	-	0.004	**0.011**	-	-	-	-	-	-
	Lead (Filtered)	mg/L	0.001		**0.0066**		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.01	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
MAH	1,2,4-trimethylbenzene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	1,3,5-trimethylbenzene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Total MAH	mg/L	0.003				<0.003	<0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.003
	Isopropylbenzene	µg/L	1		**40**		<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
	Styrene	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
Metals	Aluminium	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	0.3	0.61	-	-	-	-	-	-
	Arsenic	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	0.006	0.07	-	-	-	-	-	-
	Arsenic (Filtered)	mg/L	0.001				0.002	<0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
	Barium	mg/L	0.02				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barium (Filtered)	mg/L	0.02				0.08	<0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02
	Beryllium	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryllium (Filtered)	mg/L	0.001				<0.001	<0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
	Boron	mg/L	0.05				-	-	-	-	-	-	-	2.3	-	-	1.3	2.5	-	-	-	-	-	-
	Boron (Filtered)	mg/L	0.05				<0.05	<0.05	0.28	<0.05	<0.05	<0.05	1.1	-	<0.05	1.1	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Cadmium	mg/L	0.0002		**0.014**		-	-	-	-	-	-	-	-	-	-	<0.0002	<0.002	-	-	-	-	-	-
	Cadmium (Filtered)	mg/L	0.0002		**0.014**		<0.0002	<0.0002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0002
	Calcium	mg/L	0.5				-	-	350	39	10	3.7	320	1000	0.7	38	46	61	23	15	28	20	11	-
	Chromium (hexavalent)	mg/L	0.005		**0.02**		<0.005	<0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.005
	Chromium (III+VI)	mg/L	0.001				-	-	-	-	-	-	-	<0.001	-	-	0.004	0.36	-	-	-	-	-	-
	Chromium (III+VI) (Filtered)	mg/L	0.001				-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001	0.16	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
	Cobalt	mg/L	0.001		**0.014**		-	-	-	-	-	-	-	-	-	-	0.004	**0.035**	-	-	-	-	-	-
	Cobalt (Filtered)	mg/L	0.001		**0.014**		<0.001	<0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
	Copper	mg/L	0.001		**0.003**		-	-	-	-	-	-	-	0.002	-	-	**0.018**	**0.016**	-	-	-	-	-	-
	Copper (Filtered)	mg/L	0.001		**0.003**		**0.003**	0.002	<0.001	0.002	**0.003**	0.001	**0.008**	-	0.001	<0.01	-	-	0.001	0.002	**0.003**	**0.003**	0.001	0.001
	Iron	mg/L	0.05				-	-	-	-	-	-	-	-	-	-	11	5.2	-	-	-	-	-	-
	Iron (Filtered)	mg/L	0.05				<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05
	Lithium	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	<0.005	0.081	-	-	-	-	-	-
	Magnesium	mg/L	0.5				-	-	410	39	5.2	3.2	630	2100	<0.5	34	14	46	2.3	1.5	15	9.7	3.9	-
	Manganese	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	0.2	0.19	-	-	-	-	-	-
	Manganese (Filtered)	mg/L	0.005				<0.005	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.038
	Mercury	mg/L	0.0001		**0.0007**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mercury (Filtered)	mg/L	0.0001		**0.0007**		<0.0001	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0001
	Nickel	mg/L	0.001		**0.2**		-	-	-	-	-	-	-	0.026	-	-	0.014	0.12	-	-	-	-	-	-
	Nickel (Filtered)	mg/L	0.001		**0.2**		0.001	0.003	0.056	0.003	0.005	0.004	0.013	-	0.002	0.087	-	-	<0.001	0.001	0.002	0.001	<0.001	0.003
	Phosphorus	mg/L	0.01				-	-	0.72	0.02	0.08	0.02	0.23	0.03	0.05	2.8	0.25	11	0.02	0.05	0.03	0.03	0.01	-
	Potassium	mg/L	0.5				-	-	35	4.9	3.4	0.7	140	380	0.7	360	70	650	5.4	13	14	10	5.3	-
	Selenium	mg/L	0.001				-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-
	Selenium (Filtered)	mg/L	0.001				<0.001	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
	Tin	mg/L	0.005				-	-	-	-	-	-	-	-	-	-	<0.005	-	-	-	-	-	-	-
	Vanadium	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	-	0.005	**0.18**	-	-	-	-	-	-
	Vanadium (Filtered)	mg/L	0.005		**0.16**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Zinc	mg/L	0.005		**0.023**		-	-	-	-	-	-	-	**0.085**	-	-	**0.072**	**0.51**	-	-	-	-	-	-

						Field ID	GW18-12	GW18-3	GW2-12	GW2-3	GW3-12	GW3-3	GW8-12	GW8-3	GW9-12	GWILP	LMP02	LP02	SW STG1&2	SW STG5	SW12	SW13	SW14	SW15
						Sampled Date	12/01/2022	12/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	13/01/2022	13/01/2022	13/01/2022	13/01/2022
						LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
						Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%																		
Chemical Group	Chemical Name	Units	EQL																				
	Zinc (Filtered)	mg/L	0.005		**0.023**		<0.005	0.017	**0.21**	**0.061**	**0.053**	**0.042**	**0.082**	-	0.022	**0.22**	-	-	0.01	0.005	0.007	<0.005	<0.005	0.009
Organochlorine Pesticide	4,4-DDE	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	a-BHC	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Aldrin	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Aldrin + Dieldrin	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	b-BHC	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	chlordane	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	d-BHC	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	DDD	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	DDT	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	DDT+DDE+DDD	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Dieldrin	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Endosulfan I	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Endosulfan II	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Endosulfan sulphate	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Endrin	µg/L	0.2		**0.01**		-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Endrin aldehyde	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Endrin ketone	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	g-BHC (Lindane)	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Heptachlor	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Heptachlor epoxide	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Methoxychlor	µg/L	0.2				-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	<0.2	-	-	-	-	-	-
	Toxaphene	mg/L	0.005				-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-	<0.005	-	-	-	-	-	-
Organophosphorous Pe	Azinophos methyl	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Bolstar (Sulprofos)	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Chlorfenvinphos	µg/L	20				-	-	<20	<20	<20	<20	<20	<20	<20	-	-	<20	-	-	-	-	-	-
	Chlorpyrifos	µg/L	2		**0.04**		-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Chlorpyrifos-methyl	mg/L	0.002				-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	<0.002	-	-	-	-	-	-
	Coumaphos	µg/L	20				-	-	<20	<20	<20	<20	<20	<20	<20	-	-	<20	-	-	-	-	-	-
	Demeton-O	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Demeton-S	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Diazinon	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Dichlorvos	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Dimethoate	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Disulfoton	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Ethion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Ethoprop	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Fenitrothion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Fensulfothion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Fenthion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Malathion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Merphos	mg/L	0.002				-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	<0.002	-	-	-	-	-	-
	Methyl parathion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Mevinphos (Phosdrin)	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Monocrotophos	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Naled (Dibrom)	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Omethoate	µg/L	20				-	-	<20	<20	<20	<20	<20	<20	<20	-	-	<20	-	-	-	-	-	-
	Phorate	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Pyrazophos	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Ronnel	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Terbufos	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Trichloronate	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Tetrachlorvinphos	mg/L	0.002				-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-	-	<0.002	-	-	-	-	-	-
Organotins	Tributyltin	µg/L	12.5				-	-	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	-	<12.5	<12.5	<12.5	<12.5	<12.5	<12.5	-
Other	Butyric Acid	mg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hexanoic Acid	mg/L	5				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6:2 Fluorotelomer Sulfonate (6:2 FtS)	mg/L	0.00005				<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.00005	<0.00005	0.0021	<0.00005	0.00055	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
PAH	Benzo(b+j)fluoranthene	mg/L	0.001				-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-	-
PAH/Phenols	2,4-dimethylphenol	µg/L	3				-	-	<3	<3	<3	<3	<3	<3	<3	-	-	-	-	-	-	-	-	-

				Darwin Harbour WQO (Shoal Bay upper area ambient marine)(applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%	Field ID	GW18-12	GW18-3	GW2-12	GW2-3	GW3-12	GW3-3	GW8-12	GW8-3	GW9-12	GWILP	LMP02	LP02	SW STG1&2	SW STG5	SW12	SW13	SW14	SW15
							Sampled Date	12/01/2022	12/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	14/01/2022	13/01/2022	13/01/2022	13/01/2022	13/01/2022
							LabReport Number	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948	856948
							Matrix Type	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
Chemical Group	Chemical Name	Units	EQL																				
	2,4-dinitrophenol	mg/L	0.03				-	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	-	-	-	-	-	-	-	-	-
	2-methylphenol	µg/L	3				-	-	<3	<3	<3	<3	<3	<3	<3	-	-	-	-	-	-	-	-	-
	2-nitrophenol	µg/L	10				-	-	<10	<10	<10	<10	<10	<10	<10	-	-	-	-	-	-	-	-	-
	3-&4-methylphenol	µg/L	6				-	-	<6	<6	<6	<6	<6	<6	<6	-	-	-	-	-	-	-	-	-
	4,6-Dinitro-2-methylphenol	µg/L	30				-	-	<30	<30	<30	<30	<30	<30	<30	-	-	-	-	-	-	-	-	-
	4-chloro-3-methylphenol	µg/L	10				-	-	<10	<10	<10	<10	<10	<10	<10	-	-	-	-	-	-	-	-	-
	4-nitrophenol	µg/L	30				-	-	<30	<30	<30	<30	<30	<30	<30	-	-	-	-	-	-	-	-	-
	Acenaphthene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Acenaphthylene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Anthracene	µg/L	1		**1.5**		-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Benz(a)anthracene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Benzo(a) pyrene	µg/L	1		**0.4**		-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Benzo(g,h,i)perylene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Benzo(k)fluoranthene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Chrysene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Cresol Total	mg/L	0.01				-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-
	Dibenz(a,h)anthracene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Fluoranthene	µg/L	1		**1.7**		-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Fluorene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Indeno(1,2,3-c,d)pyrene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Naphthalene	µg/L	1		**90**		-	-	<1	<1	<1	<1	<1	<1	<1	-	<10	**400**	-	-	-	-	-	-
	PAHs (Sum of total)	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Phenanthrene	µg/L	1		**4**		-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
	Phenol	µg/L	3		**520**		-	-	<3	<3	<3	<3	<3	<3	<3	-	-	-	-	-	-	-	-	-
	Pyrene	µg/L	1				-	-	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-
Pesticides	Parathion	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
	Pirimiphos-methyl	mg/L	0.02				-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	<0.02	-	-	-	-	-	-
Phenolics	4,6-Dinitro-o-cyclohexyl phenol	µg/L	100				-	-	<100	<100	<100	<100	<100	<100	<100	-	-	-	-	-	-	-	-	-
	Phenols (Total Halogenated)	mg/L	0.01				-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-
	Phenols (Total Non Halogenated)	mg/L	0.1				-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Polychlorinated Biphenyl	Arochlor 1016	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	Arochlor 1221	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	Arochlor 1232	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	Arochlor 1242	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	Arochlor 1248	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	Arochlor 1254	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	Arochlor 1260	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
	PCBs (Sum of total)	µg/L	5				-	-	<5	<5	<5	<5	<5	<5	<5	-	-	<5	-	-	-	-	-	-
Solvents	Methyl Ethyl Ketone	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	4-Methyl-2-pentanone	µg/L	5				<5	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<5
	Acetone	mg/L	0.005				<0.005	<0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.005
	Allyl chloride	mg/L	0.001				<0.001	<0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
	Carbon disulfide	µg/L	1				<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
SVOCs	EPN	µg/L	2				-	-	<2	<2	<2	<2	<2	<2	<2	-	-	<2	-	-	-	-	-	-
TPH	C10-C16	mg/L	0.05				-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	0.24	4	-	-	-	-	-	-
	C16-C34	mg/L	0.1				-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	0.2	42	-	-	-	-	-	-
	C34-C40	mg/L	0.1				-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	<0.1	8.8	-	-	-	-	-	-
	F2-NAPHTHALENE	mg/L	0.05				-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	0.24	4	-	-	-	-	-	-
	+C10 - C36 (Sum of total)	µg/L	100				-	-	<100	<100	<100	<100	<100	<100	<100	-	530	48,700	-	-	-	-	-	-
	C6 - C9	µg/L	20				-	-	<20	<20	<20	<20	<20	<20	<20	-	<20	<800	-	-	-	-	-	-
	C10 - C14	µg/L	50				-	-	<50	<50	<50	<50	<50	<50	<50	-	130	2700	-	-	-	-	-	-
	C15 - C28	µg/L	100				-	-	<100	<100	<100	<100	<100	<100	<100	-	400	26,000	-	-	-	-	-	-
	C29-C36	µg/L	100				-	-	<100	<100	<100	<100	<100	<100	<100	-	<100	20,000	-	-	-	-	-	-
	C10 - C40 (Sum of total)	µg/L	100				-	-	<100	<100	<100	<100	<100	<100	<100	-	440	54,800	-	-	-	-	-	-
	C6-C10	mg/L	0.02				-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.8	-	-	-	-	-	-

						Field ID	TC SUMP	WW13	WW6													
						Sampled Date	13/01/2022	13/01/2022	13/01/2022													
						LabReport Number	856948	856948	856948													
						Matrix_Type	WATER	WATER	WATER													
				Darwin Harbour WQO (Shoal Bay upper area ambient marine) (applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%				Statistical Summary												
Chemical Group	Chemical Name	Units	EQL							Number of [illegible]	Number of Detects	Minimum Concentration	Minimum Detect	Maximum Concentration	Maximum Detect	Average Concentration	Median Concentration	Geometric Standard [illegible]	Number of Guideline [illegible]			
Field	SWL	mbgl					-	8.11	1.61	64	64	0.3	0.3	11.59	11.59	3.6	2.07	2.2	0			
	pH	pH		6-8.5	6-8		7.9	5.02	4.94	74	74	4.08	4.08	12.33	12.33	6.5	6.255	1.2	35			
	Electrical conductivity	uS/cm					8529	17888	65040	74	74	3.14	3.14	66319	66319	6362	1280	11	0			
	Redox Potential	mV					1.8	52.48	49.6	73	73	-200.86	ND	1517	1517	102	95.4		0			
	Dissolved Oxygen	%S		80-100			73.9	30.3	63.5	74	74	7.1	7.1	118.5	118.5	62	65.95	2	57			
	Temp	oC					30.7	28.9	28.4	74	74	24.4	24.4	35.8	35.8	29	28.8	1.1	0			
	Turbidity	ntu					40.8	-	-	69	69	0.91	0.91	11611.5	11611.5	560	26.5	12	0			
	Tokuthion	mg/L	0.002				-	<0.002	<0.002	34	0	<0.002	ND	<0.002	ND	0.001	0.001		0			
	Acetic Acid	µg/L	5000				-	-	-	6	3	<5000	5100	11000	11000	5583	3800	2	0			
	Aminomethyl phosphonic acid	µg/L	10				-	-	-	8	1	<10	80	<1000	80	386	500	5.3	0			
	Valeric Acid	µg/L	5000				-	-	-	6	0	<5000	ND	<5000	ND	2500	2500		0			
PFAS	(N-EtFOSA)	mg/L	0.00005				<0.00005	<0.00005	<0.00005	67	0	<0.00005	ND	<0.0001	ND	0.000025	0.000025	1.1	0			
	Perfluorononanesulfonic acid (PFNS)(trace)	µg/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	(8:2 FTSA)	UG/L	0.01				<0.01	<0.01	<0.01	67	3	<0.01	0.01	<0.1	0.02	0.0062	0.005	1.5	0			
	(10:2 FTSA)	UG/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	(4:2 FTSA)	UG/L	0.01				<0.01	<0.01	<0.01	67	1	<0.01	0.02	<0.1	0.02	0.0059	0.005	1.4	0			
	(N-EtFOSAA)	UG/L	0.05				<0.05	<0.05	<0.05	67	1	<0.05	0.16	0.16	0.16	0.027	0.025	1.3	0			
	(N-EtFOSE)	UG/L	0.05				<0.05	<0.05	<0.05	67	0	<0.05	ND	<0.1	ND	0.025	0.025	1.1	0			
	(N-MeFOSAA)	UG/L	0.05				<0.05	<0.05	<0.05	67	0	<0.05	ND	<0.1	ND	0.025	0.025	1.1	0			
	(N-MeFOSE)	UG/L	0.05				<0.05	<0.05	<0.05	67	0	<0.05	ND	<0.1	ND	0.025	0.025	1.1	0			
	N-methylperfluoro-1-octane sulfonamide (N-MeFOS	UG/L	0.05				<0.05	<0.05	<0.05	67	0	<0.05	ND	<0.1	ND	0.025	0.025	1.1	0			
	Sum of PFASs (n=30)*	UG/L	0.1				16.12	<0.1	0.18	67	32	<0.1	0.18	38.6	38.6	2.4	0.05	6.7	0			
	Sum of US EPA PFAS (PFOS + PFOA)*	UG/L	0.01				1.87	<0.01	<0.01	67	39	<0.01	0.01	3.1	3.1	0.23	0.03	7.1	0			
	Sum of WA DWER PFAS (n=10)*	UG/L	0.05				15.92	<0.05	0.18	67	36	<0.05	0.07	38.6	38.6	2.4	0.08	8.5	0			
	Perfluorobutanesulfonic acid (PFBS)	UG/L	0.01				8.3	<0.01	<0.01	67	25	<0.01	0.01	17	17	0.87	0.005	10	0			
	Perfluorobutanoic acid (PFBA)	UG/L	0.05				1.3	<0.05	<0.05	67	17	<0.05	0.05	<10	2	0.22	0.025	3.6	0			
	Perfluorodecanesulfonic acid (PFDS)	UG/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	Perfluorodecanoic acid (PFDA)	UG/L	0.01				0.03	<0.01	<0.01	67	6	<0.01	0.01	<0.1	0.09	0.009	0.005	1.9	0			
	Perfluorododecanoic acid (PFDoDA)	UG/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	Perfluoroheptanesulfonic acid (PFHpS)	UG/L	0.01				<0.01	<0.01	<0.01	67	3	<0.01	0.02	<0.1	0.06	0.0069	0.005	1.6	0			
	Perfluoroheptanoic acid (PFHpA)	UG/L	0.01				0.62	<0.01	<0.01	67	26	<0.01	0.01	1.5	1.5	0.079	0.005	4.7	0			
	Perfluorohexanesulfonic acid (PFHxS)	UG/L	0.01				0.39	<0.01	<0.01	67	31	<0.01	0.01	1.8	1.8	0.082	0.005	4.9	0			
	Perfluorohexanoic acid (PFHxA)	UG/L	0.01				1.9	<0.01	0.03	67	30	<0.01	0.01	13	13	0.53	0.005	8.7	0			
	Perfluorononanoic acid (PFNA)	UG/L	0.01				0.05	<0.01	<0.01	67	9	<0.01	0.02	<0.1	0.06	0.0092	0.005	1.9	0			
	Perfluorooctane sulfonamide (FOSA)	UG/L	0.05				<0.05	<0.05	<0.05	67	0	<0.05	ND	<0.1	ND	0.025	0.025	1.1	0			
	Perfluorooctanoate (PFOA)	UG/L	0.01			632	1.6	<0.01	<0.01	67	27	<0.01	0.01	1.7	1.7	0.15	0.005	6.3	0			
	Perfluorooctanesulfonic acid (PFOS)	UG/L	0.01			2	0.27	<0.01	<0.01	67	36	<0.01	0.01	<2	1.4	0.11	0.02	5.4	0			
	Perfluoropentanesulfonic acid (PFPeS)	UG/L	0.01				0.05	<0.01	<0.01	67	16	<0.01	0.01	0.24	0.24	0.014	0.005	2.3	0			
	Perfluoropentanoic acid (PFPeA)	UG/L	0.01				1	<0.01	<0.01	67	29	<0.01	0.01	12	12	0.36	0.005	7.7	0			
	Perfluoropropanesulfonic acid (PFPrS)	UG/L	0.01				0.07	<0.01	<0.01	67	12	<0.01	0.01	<1	0.2	0.021	0.005	2.7	0			
	Perfluorotetradecanoic acid (PFTeDA)	UG/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	Perfluorotridecanoic acid (PFTrDA)	UG/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	Perfluoroundecanoic acid (PFUnDA)	UG/L	0.01				<0.01	<0.01	<0.01	67	0	<0.01	ND	<0.1	ND	0.0057	0.005	1.3	0			
	Sum (PFHxS + PFOS)*	UG/L	0.01				0.66	<0.01	<0.01	67	39	<0.01	0.01	3.2	3.2	0.18	0.02	6.7	0			
	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*	UG/L	0.01				2.26	<0.01	<0.01	67	40	<0.01	0.01	4.9	4.9	0.31	0.04	8.1	0			
VFA	4-Methylvaleric acid*	MG/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0			
	Heptanoic acid*	MG/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0			
	Isovaleric acid*	MG/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0			
	Isobutyric acid*	MG/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0			
	Total VFA as Acetic Acid Equivalents*	MG/L	5				-	-	-	6	3	<5	5.1	11	11	5.6	3.8	2	0			
BTEX	Benzene	µg/L	1		900		<20	<1	<1	45	1	<1	380	380	380	10	0.5	3.9	0			
	Ethylbenzene	µg/L	1		110		<20	<1	<1	45	2	<1	2	110	110	4.3	0.5	3.4	1			
	Toluene	µg/L	1		230		<20	<1	<1	45	1	<1	120	120	120	4.4	0.5	3.4	0			
	Xylene (m & p)	µg/L	2				<40	<2	<2	45	1	<2	670	670	670	18	1	3.8	0			
	Xylene (o)	µg/L	1				<20	<1	<1	45	3	<1	36	370	370	12	0.5	4.4	0			
	Xylene Total	µg/L	3				<60	<3	<3	45	2	<3	36	1000	1000	28	1.5	3.8	0			
	C6-C10 less BTEX (F1)	mg/L	0.02				<0.4	<0.02	<0.02	39	1	<0.02	8.4	8.4	8.4	0.25	0.01	4.3	0			
Chlorinated Hydrocarbo	1,1,1,2-tetrachloroethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,1,1-trichloroethane	µg/L	1		400		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			

						Field ID	TC SUMP	WW13	WW6													
						Sampled Date	13/01/2022	13/01/2022	13/01/2022													
						LabReport Number	856948	856948	856948													
						Matrix_Type	WATER	WATER	WATER													
				Darwin Harbour WQO (Shoal Bay upper area ambient marine) (applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%				Statistical Summary												
Chemical Group	Chemical Name	Units	EQL							Number of	Number of Detects	Minimum Concentration	Minimum Detect	Maximum Concentration	Maximum Detect	Average Concentration	Median Concentration	Geometric Standard	Number of Guideline			
	1,1,2,2-tetrachloroethane	µg/L	1		500		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,1,2-trichloroethane	µg/L	1		5800		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,1-dichloroethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,1-dichloroethene	µg/L	1		900		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,2,3-trichloropropane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,2-dichloroethane	µg/L	1		2600		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,2-dichloropropane	µg/L	1		1200		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,3-dichloropropane	µg/L	1		1400		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Bromochloromethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Bromodichloromethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Bromoform	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Carbon tetrachloride	µg/L	1		320		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Chlorodibromomethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Chloroethane	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
	Chloroform	µg/L	5		1100		-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
	Chloromethane	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
	cis-1,2-dichloroethene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	cis-1,3-dichloropropene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Dibromomethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Dichloromethane	µg/L	5		5000		-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
	Trichloroethene	µg/L	1		400		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Tetrachloroethene	µg/L	1		100		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	trans-1,2-dichloroethene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	trans-1,3-dichloropropene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Vinyl chloride	µg/L	5		140		-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
Explosives	1,3,5-Trinitrobenzene	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
	1,3-Dinitrobenzene	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
	2,4,6-Trinitrotoluene (TNT)	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
	2,4-& 2,6-Dinitrotoluene	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
	2-Nitrotoluene	µg/L	100				-	-	-	10	0	<100	ND	<100	ND	50	50		0			
	4-Nitrotoluene	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
	m-Nitrotoluene	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
	Nitrobenzene	µg/L	100				-	-	-	10	0	<100	ND	<100	ND	50	50		0			
	RDX	mg/L	0.1				-	-	-	10	0	<0.1	ND	<0.1	ND	0.05	0.05		0			
Halogenated Benzenes	1,2-dichlorobenzene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,3-dichlorobenzene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	1,4-dichlorobenzene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	4-chlorotoluene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Bromobenzene	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Chlorobenzene	µg/L	1		100		-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Hexachlorobenzene	µg/L	0.2		0.2		-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0			
Halogenated Hydrocarbo	1,2-dibromoethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Bromomethane	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
	Dichlorodifluoromethane	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
	Iodomethane	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0			
	Trichlorofluoromethane	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0			
Halogenated Phenols	2,4,5-trichlorophenol	µg/L	10				-	<10	<10	34	0	<10	ND	<10	ND	5	5		0			
	2,4,6-trichlorophenol	µg/L	10				-	<10	<10	34	0	<10	ND	<10	ND	5	5		0			
	2,4-dichlorophenol	µg/L	3				-	<3	<3	34	0	<3	ND	<3	ND	1.5	1.5		0			
	2,6-dichlorophenol	µg/L	3				-	<3	<3	34	0	<3	ND	<3	ND	1.5	1.5		0			
	2-chlorophenol	µg/L	3				-	<3	<3	34	0	<3	ND	<3	ND	1.5	1.5		0			
	Pentachlorophenol	µg/L	10		33		-	<10	<10	34	0	<10	ND	<10	ND	5	5		0			
	tetrachlorophenols	µg/L	30				-	<30	<30	34	0	<30	ND	<30	ND	15	15		0			
Herbicides	2,4,5-Trichlorophenoxy-propanoic acid	mg/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0			
	Dinoseb	µg/L	100				-	<100	<100	34	0	<100	ND	<100	ND	50	50		0			
	Glyphosate	mg/L	0.01				-	-	-	8	0	<0.01	ND	<1	ND	0.38	0.5	8.4	0			
Inorganics	Alkalinity (Bicarbonate as CaCO3)	mg/L	20				390	22	33	69	37	<20	20	7600	7600	445	22	5.9	0			
	Carbonate Alkalinity (as CaCO3)	MG/L	10				16	<10	<10	69	7	<10	16	1400	1400	36	5	2.9	0			
	Nitrite + Nitrate as N	mg/L	0.05				<2.5	1.1	3.3	69	58	<0.05	0.06	220	220	6.8	1.25	6.7	0			

							Field ID	TC SUMP	WW13	WW6												
							Sampled Date	13/01/2022	13/01/2022	13/01/2022												
							LabReport Number	856948	856948	856948												
							Matrix_Type	WATER	WATER	WATER												
				Darwin Harbour WQO (Shoal Bay upper area ambient marine) (applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%					Statistical Summary											
Chemical Group	Chemical Name	Units	EQL								Number of [illegible]	Number of Detects	Minimum Concentration	Minimum Detect	Maximum Concentration	Maximum Detect	Average Concentration	Median Concentration	Geometric Standard [illegible]	Number of Guideline [illegible]
	Alkalinity (Hydroxide) as CaCO3	µg/L	20000				<20,000	<20,000	<20,000		69	2	<20000	1100000	1200000	1200000	43043	10000	2.2	0
	Alkalinity (total) as CaCO3	mg/L	20				410	22	33		69	40	<20	20	9000	9000	509	28	6.4	0
	Ammonia as N	µg/L	10	**20**	**1200**		**1,100,000**	90	**4300**		69	55	<10	10	2000000	2000000	105841	90	38	20
	Chloride	mg/L	1				1700	5400	20,000		69	69	5.7	5.7	31000	31000	2855	310	9.6	0
	COD	mg/L	25				2200	260	32		74	39	<25	27	15000	15000	476	30	5.7	0
	Kjeldahl Nitrogen Total	mg/L	0.2				1300	1.1	5.6		69	63	<0.2	0.3	2000	2000	118	1.3	11	0
	Nitrate (as N)	mg/L	0.02				<2.5	1.1	3.2		69	59	<0.02	0.02	220	220	6.5	1.1	7.8	0
	Nitrite (as N)	mg/L	0.02				<1	<0.02	0.07		69	19	<0.02	0.07	8.2	8.2	0.34	0.01	6.8	0
	Nitrogen (Total)	µg/L	200	**300**			1,300,000	2200	8900		69	68	<200	200	2000000	2000000	123678	3900	8.5	0
	Reactive Phosphorus as P	µg/L	0.01	**10**			7.6	0.09	0.82		69	44	<0.01	0.01	9.5	9.5	0.6	0.02	9.4	0
	Sodium	mg/L	0.5				1600	3000	8800		69	69	2.6	2.6	17000	17000	1695	170	9.3	0
	Sulphate	mg/L	5				<5	750	2500		69	56	<5	6	3800	3800	325	51	7.5	0
	TDS	mg/L	10				6700	12,000	41,000		74	74	19	19	61000	61000	5534	865	7.1	0
	TOC	mg/L	5				2700	<5	5.2		74	26	<5	5.2	4200	4200	153	2.5	6.2	0
	TSS	mg/L	5	**10**			68	630	10		74	61	<5	5.2	630	630	71	25	4.7	0
Lead	Lead	mg/L	0.001		**0.0066**		**0.016**	-	-		11	10	<0.001	0.004	0.075	0.075	0.015	0.011	3.6	6
	Lead (Filtered)	mg/L	0.001		**0.0066**		-	0.004	0.002		64	10	<0.001	0.001	0.023	0.023	0.0013	0.0005	2.2	1
MAH	1,2,4-trimethylbenzene	µg/L	1				-	-	-		12	0	<1	ND	<1	ND	0.5	0.5		0
	1,3,5-trimethylbenzene	µg/L	1				-	-	-		12	0	<1	ND	<1	ND	0.5	0.5		0
	Total MAH	mg/L	0.003				-	-	-		12	0	<0.003	ND	<0.003	ND	0.0015	0.0015		0
	Isopropylbenzene	µg/L	1		**40**		-	-	-		12	0	<1	ND	<1	ND	0.5	0.5		0
	Styrene	µg/L	1				-	-	-		12	0	<1	ND	<1	ND	0.5	0.5		0
Metals	Aluminium	mg/L	0.05				0.67	-	-		6	5	0.3	0.3	1.6	1.6	0.72	0.64	2	0
	Arsenic	mg/L	0.001				0.028	-	-		10	6	<0.001	0.006	0.33	0.33	0.063	0.017	14	0
	Arsenic (Filtered)	mg/L	0.001				-	-	-		8	2	<0.001	0.001	0.002	0.002	0.00075	0.0005	1.7	0
	Barium	mg/L	0.02				-	-	-		4	4	0.08	0.08	0.7	0.7	0.25	0.1	2.8	0
	Barium (Filtered)	mg/L	0.02				-	-	-		6	4	<0.02	0.08	1.1	1.1	0.23	0.085	5.8	0
	Beryllium	mg/L	0.001				-	-	-		4	1	<0.001	0.002	0.002	0.002	0.00088	0.0005	2	0
	Beryllium (Filtered)	mg/L	0.001				-	-	-		8	0	<0.001	ND	<0.001	ND	0.0005	0.0005		0
	Boron	mg/L	0.05				1.4	-	-		11	11	0.07	0.07	20	20	3.1	1.4	6	0
	Boron (Filtered)	mg/L	0.05				-	0.16	0.41		60	23	<0.05	0.06	2.9	2.9	0.24	0.025	4.2	0
	Cadmium	mg/L	0.0002		**0.014**		<0.002	-	-		10	3	<0.0002	0.0005	<0.002	0.001	0.00076	0.001	2.6	0
	Cadmium (Filtered)	mg/L	0.0002		**0.014**		-	-	-		8	3	<0.0002	0.0004	0.0018	0.0018	0.00044	0.0001	3.2	0
	Calcium	mg/L	0.5				47	380	930		69	69	0.7	0.7	2100	2100	186	36	7.5	0
	Chromium (hexavalent)	mg/L	0.005		**0.02**		-	-	-		12	1	<0.005	0.006	0.006	0.006	0.0028	0.0025	1.3	0
	Chromium (III+VI)	mg/L	0.001				0.17	-	-		7	6	<0.001	0.004	1.2	1.2	0.34	0.17	17	0
	Chromium (III+VI) (Filtered)	mg/L	0.001				-	0.005	0.002		56	9	<0.001	0.001	0.16	0.16	0.0042	0.0005	2.9	0
	Cobalt	mg/L	0.001		**0.014**		**0.037**	-	-		10	10	0.002	0.002	0.2	0.2	0.036	0.016	4.4	6
	Cobalt (Filtered)	mg/L	0.001		**0.014**		-	-	-		8	4	<0.001	0.001	0.017	0.017	0.004	0.00075	4.2	1
	Copper	mg/L	0.001		**0.003**		**0.02**	-	-		11	11	0.002	0.002	0.48	0.48	0.077	0.016	6.9	8
	Copper (Filtered)	mg/L	0.001		**0.003**		-	<0.001	**0.006**		64	42	<0.001	0.001	0.011	0.011	0.0023	0.002	2.6	21
	Iron	mg/L	0.05				8.1	-	-		10	10	0.09	0.09	18	18	5.8	4.7	8.2	0
	Iron (Filtered)	mg/L	0.05				-	-	-		8	0	<0.05	ND	<0.05	ND	0.025	0.025		0
	Lithium	mg/L	0.005				<0.05	-	-		6	3	<0.005	0.081	0.53	0.53	0.14	0.053	6.5	0
	Magnesium	mg/L	0.5				37	390	1200		69	63	<0.5	0.6	2100	2100	186	21	12	0
	Manganese	mg/L	0.005				0.17	-	-		10	10	0.025	0.025	0.94	0.94	0.27	0.195	3.1	0
	Manganese (Filtered)	mg/L	0.005				-	-	-		8	6	<0.005	0.005	0.76	0.76	0.16	0.024	9.3	0
	Mercury	mg/L	0.0001		**0.0007**		-	-	-		5	0	<0.0001	ND	<0.0005	ND	0.00009	0.00005	2.1	0
	Mercury (Filtered)	mg/L	0.0001		**0.0007**		-	-	-		8	0	<0.0001	ND	<0.0001	ND	0.00005	0.00005		0
	Nickel	mg/L	0.001		**0.2**		0.14	-	-		11	11	0.004	0.004	0.67	0.67	0.13	0.11	4.5	1
	Nickel (Filtered)	mg/L	0.001		**0.2**		-	0.15	**0.68**		64	52	<0.001	0.001	0.75	0.75	0.034	0.003	6	2
	Phosphorus	mg/L	0.01				6.9	0.5	0.99		69	66	<0.01	0.01	46	46	1.5	0.03	8.4	0
	Potassium	mg/L	0.5				560	32	160		69	66	<0.5	0.5	3400	3400	134	20	8.7	0
	Selenium	mg/L	0.001				<0.01	-	-		9	0	<0.001	ND	<0.01	ND	0.003	0.005	3.4	0
	Selenium (Filtered)	mg/L	0.001				-	-	-		8	1	<0.001	0.003	0.003	0.003	0.00081	0.0005	1.9	0
	Tin	mg/L	0.005				-	-	-		1	0	<0.005	ND	<0.005	ND		0.0025		0
	Vanadium	mg/L	0.005		**0.16**		0.081	-	-		10	7	<0.005	0.005	0.9	0.9	0.15	0.044	9.5	3
	Vanadium (Filtered)	mg/L	0.005		**0.16**		-	-	-		2	1	<0.005	0.025	0.025	0.025		0.01375	5.1	0
	Zinc	mg/L	0.005		**0.023**		**0.23**	-	-		11	11	0.005	0.005	2.6	2.6	0.44	0.23	5.5	10

						Field ID	TC SUMP	WW13	WW6													
						Sampled Date	13/01/2022	13/01/2022	13/01/2022													
						LabReport Number	856948	856948	856948													
						Matrix_Type	WATER	WATER	WATER													
				Darwin Harbour WQO (Shoal Bay upper area ambient marine) (applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%				Statistical Summary											
Chemical Group	Chemical Name	Units	EQL							Number of [illegible]	Number of Detects	Minimum Concentration	Minimum Detect	Maximum Concentration	Maximum Detect	Average Concentration	Median Concentration	Geometric Standard [illegible]	Number of Guideline [illegible]
	Zinc (Filtered)	mg/L	0.005		**0.023**		-	**0.5**	**0.93**	64	53	<0.005	0.005	0.93	0.93	0.078	0.022	4.8	31
Organochlorine Pesticide	4,4-DDE	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	a-BHC	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Aldrin	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Aldrin + Dieldrin	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	b-BHC	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	chlordane	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	d-BHC	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	DDD	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	DDT	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	DDT+DDE+DDD	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Dieldrin	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Endosulfan I	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Endosulfan II	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Endosulfan sulphate	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Endrin	µg/L	0.2		**0.01**		-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Endrin aldehyde	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Endrin ketone	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	g-BHC (Lindane)	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Heptachlor	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Heptachlor epoxide	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Methoxychlor	µg/L	0.2				-	<0.2	<0.2	34	0	<0.2	ND	<0.2	ND	0.1	0.1		0
	Toxaphene	mg/L	0.005				-	<0.005	<0.005	34	0	<0.005	ND	<0.005	ND	0.0025	0.0025		0
Organophosphorous Pe	Azinophos methyl	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Bolstar (Sulprofos)	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Chlorfenvinphos	µg/L	20				-	<20	<20	34	0	<20	ND	<20	ND	10	10		0
	Chlorpyrifos	µg/L	2		**0.04**		-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Chlorpyrifos-methyl	mg/L	0.002				-	<0.002	<0.002	34	0	<0.002	ND	<0.002	ND	0.001	0.001		0
	Coumaphos	µg/L	20				-	<20	<20	34	0	<20	ND	<20	ND	10	10		0
	Demeton-O	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Demeton-S	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Diazinon	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Dichlorvos	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Dimethoate	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Disulfoton	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Ethion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Ethoprop	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Fenitrothion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Fensulfothion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Fenthion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Malathion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Merphos	mg/L	0.002				-	<0.002	<0.002	34	0	<0.002	ND	<0.002	ND	0.001	0.001		0
	Methyl parathion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Mevinphos (Phosdrin)	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Monocrotophos	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Naled (Dibrom)	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Omethoate	µg/L	20				-	<20	<20	34	0	<20	ND	<20	ND	10	10		0
	Phorate	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Pyrazophos	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Ronnel	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Terbufos	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Trichloronate	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Tetrachlorvinphos	mg/L	0.002				-	<0.002	<0.002	34	0	<0.002	ND	<0.002	ND	0.001	0.001		0
Organotins	Tributyltin	µg/L	12.5				-	<12.5	<12.5	31	0	<12.5	ND	<12.5	ND	6.3	6.25		0
Other	Butyric Acid	mg/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0
	Hexanoic Acid	mg/L	5				-	-	-	6	0	<5	ND	<5	ND	2.5	2.5		0
	6:2 Fluorotelomer Sulfonate (6:2 FtS)	mg/L	0.00005				0.00054	<0.00005	0.00015	67	9	<0.00005	0.00007	0.0021	0.0021	0.00012	0.000025	2.9	0
PAH	Benzo(b+j)fluoranthene	mg/L	0.001				-	<0.001	<0.001	34	0	<0.001	ND	<0.001	ND	0.0005	0.0005		0
PAH/Phenols	2,4-dimethylphenol	µg/L	3				-	<3	<3	34	0	<3	ND	<3	ND	1.5	1.5		0

						Field ID	TC SUMP	WW13	WW6														
						Sampled Date	13/01/2022	13/01/2022	13/01/2022														
						LabReport Number	856948	856948	856948														
						Matrix_Type	WATER	WATER	WATER														
				Darwin Harbour WQO (Shoal Bay upper area ambient marine) (applicable to surface water only)	ANZG (2018) Marine Water 90% LOSP Toxicant DGVs	PFAS NEMP 2020 Interim Marine 90%				Statistical Summary												
Chemical Group	Chemical Name	Units	EQL							Number of	Number of Detects	Minimum Concentration	Minimum Detect	Maximum Concentration	Maximum Detect	Average Concentration	Median Concentration	Geometric Standard	Number of Guideline
	2,4-dinitrophenol	mg/L	0.03				-	<0.03	<0.03	34	0	<0.03	ND	<0.03	ND	0.015	0.015		0
	2-methylphenol	µg/L	3				-	<3	<3	34	0	<3	ND	<3	ND	1.5	1.5		0
	2-nitrophenol	µg/L	10				-	<10	<10	34	0	<10	ND	<10	ND	5	5		0
	3-&4-methylphenol	µg/L	6				-	<6	<6	34	0	<6	ND	<6	ND	3	3		0
	4,6-Dinitro-2-methylphenol	µg/L	30				-	<30	<30	34	0	<30	ND	<30	ND	15	15		0
	4-chloro-3-methylphenol	µg/L	10				-	<10	<10	34	0	<10	ND	<10	ND	5	5		0
	4-nitrophenol	µg/L	30				-	<30	<30	34	0	<30	ND	<30	ND	15	15		0
	Acenaphthene	µg/L	1				-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Acenaphthylene	µg/L	1				-	<1	<1	34	1	<1	4	4	4	0.6	0.5	1.4	0
	Anthracene	µg/L	1		**1.5**		-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Benz(a)anthracene	µg/L	1				-	<1	<1	34	1	<1	2	2	2	0.54	0.5	1.3	0
	Benzo(a) pyrene	µg/L	1		**0.4**		-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Benzo(g,h,i)perylene	µg/L	1				-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Benzo(k)fluoranthene	µg/L	1				-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Chrysene	µg/L	1				-	<1	<1	34	1	<1	2	2	2	0.54	0.5	1.3	0
	Cresol Total	mg/L	0.01				-	<0.01	<0.01	34	0	<0.01	ND	<0.01	ND	0.005	0.005		0
	Dibenz(a,h)anthracene	µg/L	1				-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Fluoranthene	µg/L	1		**1.7**		-	<1	<1	34	1	<1	4	4	4	0.6	0.5	1.4	1
	Fluorene	µg/L	1				-	<1	<1	34	1	<1	5	5	5	0.63	0.5	1.5	0
	Indeno(1,2,3-c,d)pyrene	µg/L	1				-	<1	<1	34	0	<1	ND	<1	ND	0.5	0.5		0
	Naphthalene	µg/L	1		**90**		**200**	<1	<1	39	3	<1	200	660	660	41	0.5	8.4	3
	PAHs (Sum of total)	µg/L	1				-	<1	<1	34	1	<1	169	169	169	5.5	0.5	2.7	0
	Phenanthrene	µg/L	1		**4**		-	<1	<1	34	1	<1	4	4	4	0.6	0.5	1.4	1
	Phenol	µg/L	3		**520**		-	<3	<3	34	0	<3	ND	<3	ND	1.5	1.5		0
	Pyrene	µg/L	1				-	<1	<1	34	1	<1	8	8	8	0.72	0.5	1.6	0
Pesticides	Parathion	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
	Pirimiphos-methyl	mg/L	0.02				-	<0.02	<0.02	34	0	<0.02	ND	<0.02	ND	0.01	0.01		0
Phenolics	4,6-Dinitro-o-cyclohexyl phenol	µg/L	100				-	<100	<100	34	0	<100	ND	<100	ND	50	50		0
	Phenols (Total Halogenated)	mg/L	0.01				-	<0.01	<0.01	34	0	<0.01	ND	<0.01	ND	0.005	0.005		0
	Phenols (Total Non Halogenated)	mg/L	0.1				-	<0.1	<0.1	34	0	<0.1	ND	<0.1	ND	0.05	0.05		0
Polychlorinated Biphenyl	Arochlor 1016	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	Arochlor 1221	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	Arochlor 1232	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	Arochlor 1242	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	Arochlor 1248	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	Arochlor 1254	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	Arochlor 1260	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
	PCBs (Sum of total)	µg/L	5				-	<5	<5	34	0	<5	ND	<5	ND	2.5	2.5		0
Solvents	Methyl Ethyl Ketone	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0
	4-Methyl-2-pentanone	µg/L	5				-	-	-	12	0	<5	ND	<5	ND	2.5	2.5		0
	Acetone	mg/L	0.005				-	-	-	12	1	<0.005	0.007	0.007	0.007	0.0029	0.0025	1.3	0
	Allyl chloride	mg/L	0.001				-	-	-	12	0	<0.001	ND	<0.001	ND	0.0005	0.0005		0
	Carbon disulfide	µg/L	1				-	-	-	12	0	<1	ND	<1	ND	0.5	0.5		0
SVOCs	EPN	µg/L	2				-	<2	<2	34	0	<2	ND	<2	ND	1	1		0
TPH	C10-C16	mg/L	0.05				2	<0.05	<0.05	39	9	<0.05	0.05	5.8	5.8	0.52	0.025	5.5	0
	C16-C34	mg/L	0.1				6.5	<0.1	<0.1	39	10	<0.1	0.2	42	42	2.9	0.05	7.5	0
	C34-C40	mg/L	0.1				0.2	<0.1	<0.1	39	5	<0.1	0.2	8.8	8.8	0.48	0.05	3.3	0
	F2-NAPHTHALENE	mg/L	0.05				2	<0.05	<0.05	39	9	<0.05	0.05	5.8	5.8	0.51	0.025	5.4	0
	+C10 - C36 (Sum of total)	µg/L	100				8900	<100	<100	39	10	<100	200	48700	48700	3629	50	8.2	0
	C6 - C9	µg/L	20				<400	<20	<20	39	1	<20	3200	3200	3200	122	10	3.8	0
	C10 - C14	µg/L	50				1800	<50	<50	39	8	<50	50	5900	5900	484	25	5.3	0
	C15 - C28	µg/L	100				6700	<100	<100	39	10	<100	100	26000	26000	2171	50	7	0
	C29-C36	µg/L	100				400	<100	<100	39	7	<100	100	20000	20000	1036	50	4.1	0
	C10 - C40 (Sum of total)	µg/L	100				8700	<100	<100	39	10	<100	200	54800	54800	3825	50	8.3	0
	C6-C10	mg/L	0.02				<0.4	<0.02	<0.02	39	1	<0.02	10	10	10	0.3	0.01	4.4	0

| | | | | | BTEX | | | | | | Explosives | | Herbicides | Inorganics | | | | | | | Metals | | | PFAS | | | | | | |

	Perfluoropentanoic acid (PFPeA)	Perfluoropropanesulfonic acid (PFPrS)	Perfluorotetradecanoic acid (PFTeDA)	Perfluorotridecanoic acid (PFTrDA)	Perfluoroundecanoic acid (PFUnDA)	Sum (PFHxS + PFOS)*	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CRCCARE 2011 Soil HSL for Direct Contact, HSL-D Com/Ind							
0-1m							
CRCCARE 2011 Soil HSL for Direct Contact, Intrusive Maintenance Wor							
0-3m							
NEPM 2013 Table 1B(6) ESLs for Areas of Ecological Significance, Fine S							
NEPM 2013 Table 1B(6) ESLs for Comm/Ind, Fine Soil							
0-2m							

Field ID	LocCode	Sample Depth	Ran Sampled Date	Matrix_Description							
BCFP01	BCFP01	Surface	8/12/2021	Flood plain sedime	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
MCFP01	MCFP01	Surface	8/12/2021	Flood plain sedime	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Statistical Summary

Number of Results	2	2	2	2	2	2	2
Number of Detects	0	0	0	0	0	0	0
Minimum Concentration	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Minimum Detect	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Maximum Detect	ND	ND	ND	ND	ND	ND	ND
Average Concentration							
Median Concentration	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Geometric Standard Deviation							
Number of Guideline Exceedances (Detects Only)	0	0	0	0	0	0	0

APPENDIX

C

LABORATORY ANALYSIS REPORTS

APPENDIX

D

SOP AND SWMS

PN3.04 - Groundwater Sampling Procedure

1 INTRODUCTION

This document specifies the procedure of Cardno's adopted techniques for groundwater sampling for environmental investigations.

2 PURPOSE

This document provides guidance for the use of various sampling techniques in order to obtain representative and unadulterated samples of groundwater from monitoring bores for the purpose of physical and chemical analysis of water samples.

3 GLOSSARY

1. **Bore**: Any bore, well or excavation or any artificially constructed or improved underground cavity used or to be used for the purpose of (a) the interception, collection, or storage of groundwater; or (b) groundwater observation or the collection of data. Source: EPA *Groundwater Sampling Guidelines* Publication 669 April 2000.
1. **Well**: a licensed groundwater bore.
2. **SWL**: Standing / Static Water Level 1) the elevation or level of the water table in a well when the pump is not operating. 2) the level or elevation to which water would rise in a tube connected to an artesian aquifer, or basin, or conduit under pressure. Source: US EPA website
3. **RWL**: Relative Water Level – surveyed and calculated water level referenced to an arbitrary fixed elevation level.
4. **AHD**: Australian Height Datum
5. **Recovery**: the difference between the measured water level in an observation well at a given time after pumping stops and the SWL?
6. **TOC**: Top of Casing
7. **Stick up**: The distance between TOC and ground level (can be negative when below ground level)
8. **Purging**: The process of removing stagnant water from a bore before sampling.
9. **Development**: The process of removing fine sand, silt and clay from the bore annulus around the bore screen and breaking down the drilling mud on the borehole wall.
10. **NEPM 2013**: National Environment Protection Measure 2013

4 SCOPE

The scope of this document covers the following list of groundwater monitoring activities;

1. Preparation for Fieldwork
2. Inspection of Bore
3. Water Level measurement
4. LNAPL / PSH measurement
5. Bore Purging

6. Sampling
7. Sample Handling & preservation
8. Quality control – Replicates
9. Quality control – Decontamination
10. Sample handling, forwarding and CoC
11. Field Records

4.1 Related Procedures/Forms

1. F3.01 ESA Planning Procedure
2. F3.01 Site Investigation Planning Checklist
3. F3.01 Field Work Daily Report
4. F3.01 QC Sample Register
5. F3.04 Groundwater Sampling Field Record
6. CLP-P2-4-QF01 Chain of Custody
7. PN3.04 Groundwater bore volumes
8. PN3.04 Slug test procedure (aquifer response)
9. Bore installation
10. PN3.04 Bore Development Procedure
11. Pumping tests
12. Equipment Field Calibration
13. Waste Management

4.2 Preparation for Field Work

Prior to commencing fieldwork the following preparations are required; Adapted from “EPA Groundwater Sampling Guidelines Publication 669 April 2000” and NEPM 2013

1. Define objectives of groundwater sampling program (to be found in Sampling and Analysis Plan (SAP) for specific site) – PM to complete as per NEPM requirements setting out data quality objectives
2. Review and compile results from past groundwater sampling events (where available) – PM to complete
3. Site specific parameters to be sampled & analysed (to be found in SAP and Work Request Form - WRF)
4. Number / frequency of samples to be collected (to be found in SAP and WRF)
5. Bore details – location, depth & diameter of bore, depth and length of screened interval, depth to groundwater, drilling, installation and development details (to be found in Bore Logs)
6. Previous field sheets, borelogs, water level gauging/purging data and bore construction details.
7. Sampling protocol – purging procedure and justification for this method, in-field measurements, sampling technique and equipment, filtration and preservation requirements, and QA/QC (to be found in this procedure and the SAP and WRF for site specific details)

8. Organise sample storage and transportation to the laboratory (NATA accredited) and order appropriate sample bottles, trip blanks and preservatives as required
9. Order, check and or/calibrate sampling equipment and/or field meters and ensure they are working correctly (either using pre-calibrated meters provided by rental company or calibrated prior to or during field events, where required following calibration procedures/manuals)
10. Sample forms and documentation including chain of custody forms, groundwater sampling field records etc
11. Notification to owner of bore(s) of proposed sampling and arrange for access (e.g. inductions, keys, etc).

4.2.1 Sample Registers

A sample register should be used for more than 15 bores located on a site. Site specific field records should be prepared in conjunction with the PM depending on the nature of the project and the number of monitoring events planned (refer to SAP and/or WRF for details).

4.2.2 Equipment Checklist

Please refer to F3.01 Site Investigation Planning Checklist for equipment required for groundwater sampling.

All equipment for groundwater sampling shall be stored in a dust free environment. Pumps and tubing shall be shrouded in plastic wrap to prevent ingress of contaminants during shipment of equipment.

4.3 Inspection of Bore

When inspecting the groundwater bore prior to sampling the following details should be recorded;

1. Bore condition / Locked? Damaged? Inundated?
2. Type of protective cap / cover
3. Water level measurement point
4. RL of measurement point (m AHD)
5. Casing stick up
6. Casing type and diameter
7. Any other useful observations

All details are to be recorded on document F3.04 Groundwater Sampling Field Record

4.4 Water Level Measurement

The first operation performed at each bore is to open the well cover and remove the well cap and measure for vapours particularly at bores known to have highly contaminated groundwater. The PID is held just over the top of the well and a measurement is recorded in your field notes as well as a description of odours identified. Refer to your JSA if vapours continue to emanate from the bore above action levels set for the assessment within the breathing zone.

Prior to groundwater purging/sampling a water level shall be recorded. This should be performed with a water level dip meter or an interface probe. If it safe and practical to do so, all groundwater wells should be measured on the same day, to provide accurate and consistent water levels (refer to WRF for details).

1. Measurements shall be made of the distance between the water level and the top of the protective casing (TOC) from a marked measurement point on the TOC, but must be referenced to ground level when bores have been surveyed to Australian Height Datum (AHD).
2. The water level dip meter should be lowered slowly down the well, until a beeping sound is heard. Slowly lift the probe up until no sound is heard and lowers the probe even slower than the first time to ensure the beeps indicate a water level within the well. Record this measurement as standing water level in meters below top of casing (TOC) ("SWL .m TOC to the nearest mm") on the document F3.04 Groundwater Sampling Field Record.
3. Record the depth of the well lowering the dip meter to the bottom of the bore. Record this level as the depth of the bore (m TOC). Turn the dip meter off to remove the beeping sound.
4. Decontamination of the dip meter should occur between each bore. Refer to section 4.7.1
5. Particular care needs to be taken to the probes during fieldwork and during decontamination process which includes rinsing the probes and retracting the tape of the dip meter evenly without kinks, twists or knots.

4.5 NAPL / PSH Measurement

Non aqueous phase liquids (NAPLs) are organic fluids that are immiscible (do not mix) with water. They can be lighter (LNAPL) or denser (DNAPL) than groundwater. Where LNAPL is present within a bore, it is not possible to obtain a representative sample of groundwater for dissolved phase of petroleum components. (EPA *Groundwater Sampling Guidelines*, Pub 669).

The following points should be noted for when sampling NAPLs;

- Sample at the interval where the NAPL is most likely to be encountered if fingerprint analysis is required.
- Do not purge before measuring the thickness of or sampling from the NAPL layer
- Measure LNAPL thickness with an interface probe
- These wells where LNAPL may be located should be measured last. Groundwater wells located up gradient or less contaminated should be measured first (see WRF for details for site).

1. To measure the interval where NAPL is present lower an oil/water interface probe down the bore very slowly from the measuring point. It is important that the interface meter is lowered slowly so that the probe is not plunged through the thickness of NAPL present into the dissolved phase water. The probe will not differentiate between the two layers if this occurs and it is best to start again. Lower the probe slowly until a continuous tone is heard at the top of the NAPL. Record this level as depth to product and continue to slowly lower the probe until a beeping sound is heard. Record this level as depth to water. Once probe is submerged in water pull the probe back up slowly to confirm the measured thickness of LNAPL. *Note : It is important that the interface probe is lowered through the water and pulled back slowly so that LNAPL is not caught in the instrument (probe head), which can give a false recording of LANPL thickness. The Interface probe can also be used for measuring DNAPL at base of bore using same approach* Record the depth of the well lowering the dip meter to the bottom of the bore. Record this level as the depth of the bore. Retrieve the interface probe from the bore and thoroughly decontaminated probe. Refer to section 4.7.1.
2. The thickness of NAPL is the difference between the depth to product and the depth to water. To confirm the presence of NAPL use a bailer to retrieve a sample. Ensure that you use a clear bailer and only collect the top layer of liquid. Approximately half to three quarters of a bailer so you can distinguish between the water and the NAPL. Again slowly lower the bailer, do not plunge it through the NAPL.
3. Clear photos should be taken of the bailer with NAPL present as well as indicating the bore number on the bailer. Record colour and appearance of NAPL on sampling sheet.

Please refer to the EPA Groundwater Sampling Guidelines Pub 669 for further information about sampling NAPLs and a separate procedure to collect LNAPL samples for specific analysis. (Preparation of a separate procedure to undertake this task is in progress).

To sample NAPL a syringe or bailer can be used to transfer into a vial. Check with your laboratory to the volumes required for fingerprint analysis.

4.6 Bore Purging

In order to ensure that each sample of water is representative of the groundwater in the formation outside the bore and unaffected by the bore or its connection with the atmosphere, each bore must be purged. A rule of thumb used for purging is to remove three bore volumes, based on the casing volume plus 30% of the sand pack annulus volume. Purge volumes can be reduced by the use of low flow pumping equipment (e.g. bladder pumps or peristaltic pumps) using field parameter stabilisation to determine the end point of purging instead of bore volumes (see instructions below), which may produce a large volume of contaminated water requiring disposal.

For a quick calculation of purging volumes for groundwater bores the water column (depth of the well-SWL) multiplied by 5 should be used for a 50mm well. Estimates of the amount of purging required before going into the field if data from previous groundwater monitoring events is not available. Bore volume must be calculated before purging each well and recorded on F3.04 GW Sampling Field Record.

The following methods can then be used to purge a well before sampling (refer to WRF for method to be used for specific site):

1. Bailing
2. Connecting twine to a bailer, lower it down into the bore/monitoring well until it is fully submersed.
3. Lift the bailer one or two times in the water column to ensure the bailer is full and remove the groundwater from the well.
4. At each bore volume record the field parameters of a small sample as described further below. Keep removing water until the field parameters stabilise or the bore becomes dry.
5. Sampling can occur if the bore becomes dry and the bore has recovered. However contact the PM and confirm this procedure. The bailer can be left in the well with the twine secured until sampling or further purging is undertaken.
6. Record the time the sampling commenced and concluded in your field notes.

Low Flow Pumping

1. Connect a submersible low flow pump to a controlled flow cell powered by a generator or bottled gas cylinder. (Set up and use of this method requires training in the field).
2. Lower the pump to the middle or just above the middle of the well screen interval. Be consistent with either sampling depth through the groundwater monitoring event. Use the dip meter to check the depth of the pump before commencing.
3. Lower a water level meter inside the well and record the standing water level with the pump in the well.
4. Set the pump to remove water at low cycle (e.g. 0.1L/min) and monitor the standing water level. Set the pump to remove water at rate where the standing water level does not drop more than 10cm below the original water depth.
5. If draw down is continuously greater than 20cm and the aquifer is not recovering on the lowest pump cycle - Stop using this method and seek alternative purging methods in discussion with the project manager such as bailing or additional time to proceed with low flow sampling at a very slow rate.

6. Collect field parameters during this process refer to section 4.5.1. Once stabilisation of parameters and water levels occur, sampling can commence refer to section 4.6. This method works best in fractured rock aquifers. Seek approval from the project manager before changing the sampling method. Record all changes to planned sampling methods for each bore.

Pumping Bore Volumes (Set up and use of this method requires training in the field).

- Using a hydrostatic (Waterra) pump attached to a monitoring bore can remove a large volume of water and useful for deep bores, particularly at landfills.
- Attach a non-return valve to a plastic tubing of suitable diameter. Lower the tubing into the bore and turn the pump to a rate where water is removed at a rate that can be collected. Collect field parameters after each calculated bore volume and sample once these parameters have stabilised.

Note that NEPM 2013 highlights that purging via bailing or pumping is less preferred to low flow sampling. A justification for the purging selection should be included in the planning stage. Refer to section 4.5, dot 6 as well as alternative methods if low flow sampling is not appropriate. Consideration of the geological formation, bore development and objectives of the sampling is required to select an alternative method.

4.6.1 Collection of Field Parameters

A critical part of purging during each method outlined above is the collection of field parameters of the extracted groundwater. This is to ensure to collect water that is representative of the aquifer and not the stagnant water present in the well or just used to take chemical readings. This connection with the aquifer can be measured using physico-chemical parameters relevant to the conditions, but pH and electrical conductivity are the most commonly used for this purpose. It is recommended that at least three bore volumes should be removed before accepting a stable pH as evidence of effective purging (unless a low flow purging method is used), in some cases one bore volume may be all that can be purged. The multi port flow cell allows these parameters to be measured continuously for methods where a continuous flow of water is extracted. Or the probes on a water quality meter can be used for a small sample of groundwater collected in a small container after each bore volume. This water must not be used for sampling.

The EPA Groundwater Sampling Guidelines state that the following parameters may be considered stable when three consecutive readings (obtained several minutes apart) are within;

7. ± 10% for dissolved oxygen (DO)
8. ± 3% for electrical conductivity
9. ± 0.1 for pH
10. ± 10 mv for redox potential
11. +/- 10% Temp (°C)

Purging the bore dry is not recommended as this may expose the sample to air producing an unrepresentative sample. However this does occur in some formations that are slow to recover. Discuss other sampling methods for such wells if this is the case with the PM.

The record of purging and collecting field parameters shall be recorded on F3.04 GW Sampling Field Record at each bore volume or after every few minutes of purging. This should include information about water level recovery rates, field parameters and any other observations including colour, turbidity, odour, unusual signs.

4.7 Sampling

Groundwater samples shall be obtained following bore purging and using the appropriately preserved and pre-labelled (see further below for labelling instructions) sample bottles provided by the laboratory.

1. Before the sample is taken the water quality field measurements should be taken using the flow cell. Results shall be immediately recorded on the field recording sheets.
2. The pump discharge hose or bailer nozzle (using a low flow discharge nozzle provided with the bailer) shall be placed as close as practicable to the bottle neck such that the water is not aerated as it enters the bottle.
3. The bottle shall be filled completely minimising or avoiding turbulent filling, by slightly holding bottles inclined from the vertical and letting water flow down the sides of the bottles.
    - When bailing adjust the sampling nozzle to a low stream over a bucket then fill vials as full as possible. The lid of the vial can be filled, then tipped over the vial to form a meniscus
    - When low flow sampling reduce the flow rate to fill sample vials and the lid and repeat as above.
4. The bottle cap shall be firmly fitted to exclude air or volatiles from the sample straight away
5. Sampling of groundwater in vials and glass jars require a convex meniscus to ensure air does not enter the sample jar. Once the cap is firmly fitted turn over the sample vials or jars and check for any air bubbles. If air bubbles are observed re-open sample container and top up as described above and repeat procedure until no air bubbles are observed.
6. Multiple sample containers may need to be filled to satisfy the varying preservation requirements for testing of different analytes or laboratory quality control requirements. This includes extra bottles as outlined in the NEPM 2013. Refer to your SAP/WRF, project manager or laboratory for bottle and sampling requirements.
7. Observations should be recorded during sampling including sample location, sample turbidity, odour, presence of any NAPLs and colour and recorded on the field recording sheets.
8. Field filtering is required where the water is turbid, particularly where samples are preserved in acid for metals analysis. Filtering should occur in the field during sampling to ensure sample results are indicative of sampling conditions in the aquifer.
9. Filtering can be undertaken by applying vacuum or pump pressure. Either inline filters can be attached to the sample tubing outlet (for pumped bores) or sample needs to be transferred into another container (e.g. syringe with filter attached or a filter jar with vacuum pump). The recommended filter pore size is 0.45um. Dedicated filtering devices should be used for each groundwater bore that is sampled.
10. Alternatively as a secondary option in consultation with the PM, if field filtering cannot be performed in the field an **unpreserved** sample container can be used to collect the sample, the sample will be chilled and shipped to the laboratory with minimum delay. The laboratory should be informed of the need to filter immediately on receipt of the sample (to be recorded on COC).

4.7.1 Naming Groundwater Samples

Samples shall be named consistently and number order for each site as follows:

1. MW01_(insert depth) for monitoring wells,
2. QC01_(insert date) for quality control samples such as duplicates, triplicates, field, rinsate and trip blanks.

Sample container labelling, preservation and storage shall be in accordance with the Australian Standard (AS 4482.1-1997) and will need to include:

3. Name of the sampling location on the side and lid of the jar or bottle

4. Site location (suburb)
5. Job Number
6. Date of Sampling
7. Initials of the Sampler

4.8 Sample Quality Control and Quality Assurance:

4.8.1 Duplicates and Triplicates

A minimum of one duplicate and one triplicate sample shall be taken for every 20 primary samples collected (refer to SAP/WRF for site specific details). The duplicate and triplicate samples shall be collected as follows:

1. A duplicate and triplicate sample should be collected at the same location as the primary sample at predetermined locations and/or locations where contamination is identified. Three samples from the one location aims to confirm the presence of contamination on the site and cross check the laboratory analysis program.
2. Duplicates / triplicates should include blind and split samples taken immediately at the same time as the primary sample. Samples collected for duplicates, triplicates and laboratory duplicates should be filled at the same time and not one bottle at a time. Samples should be numbered to hide the identity of the primary sample.
3. Three bottles are labelled (refer to naming below) and sample is evenly distributed over each jar.
4. Each of the three bottles are filled to the top as quickly as possible to minimise the loss of VOCs without soils caught up in the thread and the jar cap is screwed on tight.
5. The primary location where duplicate and triplicate sampling occurred is recorded on Cardnos QAQC record sheet.
6. Additional duplicates and triplicate samples can be collected to further assess contaminated areas on the site. These samples can be placed on hold pending analysis of the primary sample.
7. The duplicate sample shall be labelled QC01 or sequential numbering order for QC samples taken at that site, and shall also be entered on the F3.01 QC Sample Register and the F3.04 GW Sampling Field Record, in the space provide for "Duplicate Reference".
8. For large sites where multiple field crews are conducting work simultaneously a site specific QC register shall be prepared by the field or project manager so that each quality control sample is recorded correctly and uniquely (refer to site specific SAP/WRF).

4.8.2 Rinsates, Field Blanks and Trip Blanks.

Rinsates, Field Blanks and Trip Blanks allow for a high level of quality when sampling groundwater in the field. Minimum requirements for control samples are subject to the specific requirements of the project (see SAP/WRF for site specific details) but as a minimum, they are as follows:

1. **One rinsate** collected per day of a piece of equipment that is in regular contact with the samples. Eg a sample tube, the pump, a glove. A rinsate blank is used to check the effectiveness of re-useable equipment decontamination; therefore it can be undertaken at the end or close to the end of each day.
2. **One rinsate** shall be collected in the sample bottles and filling them with de-ionised water supplied by the laboratory. The water is decantered over the appropriately selected piece of equipment. The bottles are filled to the top. The QA/QC sampling requirements should be taken from the WRF and SAP.

3. **One field blank** is generally collected per day, but specifics depending on the sampling regime of the project (see SAP/WRF). A field blank shall be collected in the sample bottles and filled using de-ionised water supplied by the laboratory. The water is decantered into the bottles and filled to the top. A field blank is to assess the potential for contaminants in the laboratory water or in the ambient air in the vicinity of sampling to effect the results.
4. **One trip blank** per esky. Trip blanks are supplied by the laboratory with the sample containers prior to the sampling event and are placed in the eskies. The trip blank is a control sample to check if that sample integrity is not lost during transit to the laboratory, particularly for the loss of volatile compounds.
5. All QAQC samples discussed above are handled as follows:
   - These samples are placed on ice and are should remain chilled from collection on site to delivery to the laboratory under chain of custody.
   - Labelled as per section 4.8
   - Correctly recorded on the COC for analysis as per section 4.8, refer to the SAP/WRF or PM for analysis requirements.
   - Record the correct primary sampling and control details on a separate record sheet. F3.01 QC Sample Register

4.8.3 Equipment Decontamination

Decontamination is the process of neutralizing, washing, rinsing and removing material from exposed surfaces to minimise cross contamination of samples from sampling equipment.

As a minimum equipment such as low flow pumps, dip meters or grab samplers used to collect water samples shall be washed with biodegradable and phosphate free detergent and rinsed with tap and distilled water. Three buckets shall be set up prior to sampling to undertake this process as follows:

1. Bucket 1: Filled with water and decon solution for washing and scrubbing (if required) field equipment in contact with samples
2. Bucket 2: Filled with tap water to rinse equipment of detergent
3. Bucket 3: Filled with distilled water to further rinse equipment of detergent
4. Remove soil adhering to the sampling equipment. Then wash the equipment by scraping, brushing or wiping with a brush using water and decon bucket 1.
5. Rinse thoroughly in Bucket 2 with tap water.
6. Rinse thoroughly in Bucket 3 to remove detergents and dry with disposal towels.
7. Repeat steps above between each bore/sampling location

4.9 Sample Handling & Preservation

Sample bottle labelling, preservation and storage shall be in accordance with Australian Standard AS2031.1 Preservation & Storage of Water Samples. Samples shall be preserved according to the requirements of testing for the analysis required, for example acid preservation, freezing etc. Appropriately pre-preserved sampling containers need to be obtained from the laboratory prior to the field mobilisation for the analytes required (as per the WRF and SAP).

4.10 CoC and Primary and Secondary Laboratories

Chain of Custody (CoC) forms are used for the purpose of certifying the integrity of samples between the time taken and when received at the laboratory. The COC is a legal document for transporting groundwater samples and requesting analysis from the primary/secondary laboratory. The following

sequence of actions and requirements shall be used to prepare separate COC forms F3.01 Chain of Custody for the primary and secondary laboratory when sending groundwater samples:

1. At the completion of the sampling event (or day of sampling), the samples shall be removed from the Eskies and a check made that all sample bottles are present. These should then be checked against the bore location list to ensure that all bores have been sampled.
2. Pack the samples bottles in the Eskys in an upright position and ensure that seals or caps are secured to prevent leakage. Pack the supplied freezer bricks evenly around the water samples. Ensure that samples are packed to prevent breakage during transport by using bubble wrap.
3. The sample number, details of each container type to be placed in each Esky, location and depth of the sample, time of sampling, and details of the preservative added shall be entered onto a CoC Form.
4. The address of the laboratory, phone number and contact person is completed on the COC.
5. The analysis requested and which samples will be placed on HOLD. The correct laboratory codes for the analysis requested written next to the analysis requested. Specific project quote numbers or codes for specific analysis or special rates should also be included. This is information should be in the WRF and discussed with the PM on site. If this is not practical, samples on the COC can be placed on HOLD, with a supplementary COC sent within 24-48hours of the samples being sent.
6. Correct names of the samples with the corresponding sample jars including all quality control samples are recorded.
7. Field observations of strong odours or signs of contamination of particular samples are added on COC
8. The requested turnaround times. Eg Standard (5 days), Fast tracked (3 days), Urgent (24 or 48 hrs). Turnaround times within 5 days require confirmation with the laboratory prior to the sampling.
9. The names/signatures of the sampler and/or the person relinquishing the sample are added. The COC is signed by the courier picking up the samples (either from the office or in the field) is added.
10. Secure the lids on the Eskies and tape the lids in place with packing tape.
11. A copy of this signed COC form is kept as a record of dispatch to the laboratory and is placed inside the respective eskies in a plastic bag (such as a GLAD zip lock bag).

4.11 Field Notes & Fieldwork Requirements

1. Attend a kick off meeting with the project manager or project associate
2. Prepare a job safety analysis and/or HASP
3. Confirm sample naming convention for the site
4. Good on site practices and housekeeping (keep a tidy work area):
5. Call into the PM or nominated buddy at the start and end of each day and for any expected events.
6. The order of sampling soil bores is from up gradient or least contaminated bores, moving closer to bores located near source areas. The safety of staff and the practicality of undertaking sampling in this order takes precedence over sampling in this order (refer to SAP/WRF and discuss with PM).
7. All sections of the field notes must be filled in out in the field and are legible for someone else to read and transfer electronically if required. The vehicle or site office on site can be used during periods of inclement weather.
8. Refer to the waste management procedure for further guidance. As a minimum the field supervisor responsibility includes the following:

- Safe and secure location of drums, skip bins or bulky bins to collect “waste” generated from field assessments. The location of drums should be confirmed with the PM.
- Correct labelling of drums for soil or groundwater waste on the side of the drums with stickers provided by the waste contractor providing the drums.
- Delivery and pick up drums should occur at the start and conclusion of the fieldwork duration. If further drums are required these can be arranged by the field supervisor in conjunction with the PM. Waste transport certificates need to be completed with the waste contractor and copies of these documents kept safely with the field notes
- Your field notes should include the number of drums delivered, date, time and the number of drums collected which is full, part full or empty.
- Waste PPE, consumables such as bailers, gloves or tubing should be placed in drum on site and labelled correctly.
- All field notes should be scanned into the fieldwork folder at the conclusion of the fieldwork program.
- Data Quality Management requirements should be discussed with PM or team leader when results are received from the laboratory.

9. Clean up and secure sampling location to conditions as found prior to sampling prior to leaving location.

Specific project requirements will be undertaken for transportation of samples due to varying analysis and holding times and this shall be confirmed and pre-arranged by the field supervisor with the PM prior to commencing work on the site.

5 References

Australian/New Zealand Standard (1998). AS/NZS 5667.11:1998. Water Quality - Sampling, Part 11: Guidance on Sampling of Groundwaters.

Sundaram, B., Feitz, A., Caritat, P. de, Plazinska, A., Brodie, R., Coram, J. and Ransley, T., 2009. Groundwater Sampling and Analysis – A Field Guide. Geoscience Australia, Record 2009/27 95 pp.

NEPM (National Environment Protection Measure) February 2013.

EPA Publication 669, Groundwater Sampling Guidelines, April 2000

Byrnes, M. E. 2009. Field Sampling Methods for Remedial Investigations. Second Edition, CRC Press, 322pp

Nielsen, D.M. & G.L. Nielsen, 2007. The Essential Handbook of Ground-Water Sampling. CRC Press, 309pp.

F3.04 – Groundwater Sampling Field Record

Site / Project:		Bore ID Number:
Client:		Job No.
Person Sampling:		Initials:
Bore / Site Details		
Bore Condition / Locked?	Type Protect. Cap / Cover:	Bore Depth (bTOC):
Inner casing/screen type & diameter:	Screen interval (bgl):	SWL (bTOC)
WL Measurement Point	RL of measurement point (mAHD)	SWL Date/Time
Other Observations on Bore/Site		
Bore Purge Data		
Purge method:	Bore Volume (L):	Purge Date:
Purge rate (L/min):	Total Purge volume (L):	LNAPL / PSH Thickness (mm) *None / ……mm*

Purge Field Physicochemical Measurements:

	Reading1	Reading 2	Reading 3	Reading 4	Reading 5	Reading 6	Reading 7	Reading 8
Start Time:								
DO (mg/L) ±10% (or ±0.2 if DO<2 mg/L)								
EC (µS/Cm) ±3%								
pH ±0.1								
Eh (mV) ±10mV								
Temp (^{O}C)								
SWL (m) after								
Cum. Volume (L)								
Water Colour								
Turbidity ±10%								
Other Observations / Notes								

Sample Container & Preservation Data					
Number of sample container: (Include QC samples)	1	2	3	4	5
Container Volume					
Container Type					
Filtration					
Preservation					
Sample Number (for Lab ID):					
QC Dup Sample No.:					

PN3.08 - Surface Water Sampling Procedure

1 Purpose

This document specifies the procedure for conducting surface water sampling.

2 Scope

The procedure provides guidance for the collection of surface water (e.g. creek, river, dam) from a surface water body for laboratory analysis or testing for field parameters on site.

3 Equipment

The equipment required for surface water sampling can change depending on the nature of the surface water body that requires sampling. The following pieces of equipment and fieldwork sheets may be required:

1. Site specific JSA
2. Appropriate PPE to site conditions & potential contaminants of concern
3. Sampling plan
4. Surface water sampling equipment:
    - Telescopic scoop
    - Van Dorn sampler
    - Sampling containers
5. Sampling containers as required for analysis
6. Chain of Custody
7. Eskies & ice
8. Water quality meter
9. Dip meter (potentially)
10. GPS
11. Surface water sampling record F3.08 Surface Water Sampling Field Record

Additional equipment (e.g. boat) may be required depending on the nature of the surface water body to be sampled and can include, but not limited to, the following scenarios:

1. Shore line (e.g. beach) from ocean/ bay
12. Creek and/ or river
13. Dam, pond, lake and/ or wetland
14. Flooded excavation
15. Drain

4 Procedure

4.1 Preparation

1. Site specific JSA must be prepared and reviewed to identify any hazards that could potentially be at the site or associated with the sampling method. This may include:
   a) Unstable ground
   b) Slippery/ wet surfaces
   c) Access constraints
   d) Hazards involving sampling from a vessel (if applicable); see . T:\OHS Management System\OHS Safe Work Procedures\SAFE WORK PROCEDURE Small Water Craft.doc
   e) Flowing water or stagnant water
2. Establish the sampling objectives to select the correct sampling method and equipment:
   a) Required number and depth of samples
   b) Site sampling method using the correct sampling equipment to safely achieve the objectives of the sampling fieldwork (see Table 1).

Table 1: Surface Water Sampling Methods & Different Sampling Equipment

Sampling Equipment	Sampling Method Comments
Telescopic scoop 	▪ Multiple samples at near surface only ▪ Not suitable for multi depth sampling ▪ Not suitable for deeper water sampling (i.e. <3.0 m) ▪ Sample from embankment, vessel and/ or fixed structure over water
Van Dorn Sampler (Horizontal Water Sampler) 	▪ Multiple samples at varying depths ▪ Suitable for deep water sampling (i.e. >3.0 m) ▪ Able to sample in flowing water environments (Note: difficult to ensure sampler is at required depth in high flowing water environments due to under currents) ▪ Sample from vessel or structure over water
Sample Container	▪ Shallow water (i.e. <0.5 m) ▪ Flowing water (at low flow rates) ▪ Stable ground & easy access to sampling point

3. Establish if in situ water quality parameters are required as part of the sampling program. Ensure that the water quality instrument has the necessary capabilities.
4. Establish if a dip meter is required for multi depth sampling.

4.2 Sampling Method

Surface water sampling should always be taken before sediment samples (if applicable) so as to limit sediment disturbance potentially affecting surface water samples and water quality field parameters, see Figure 1.

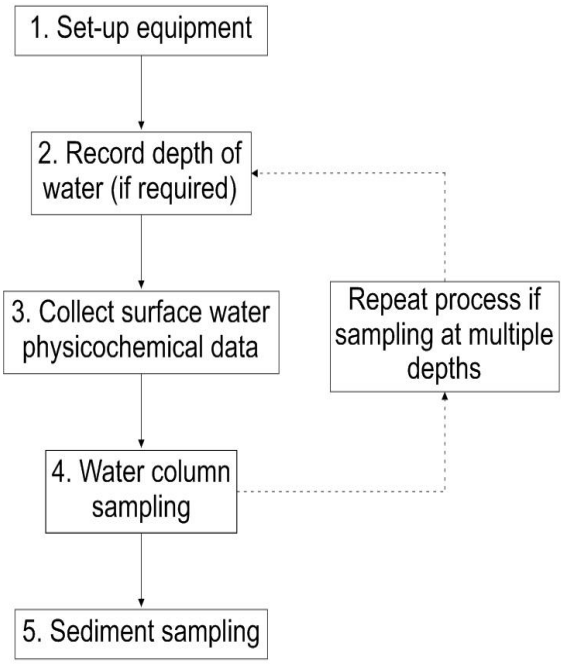


Figure 4-1 Figure 1: Surface Water Sampling Method Flow Chart

1. Slowly measure and record the depth of the surface water body using the dip meter. **Limit any water disturbance** that could occur when using the dip meter (e.g. dropping the dip meter can result in mixing of the water column).
2. Record the surface water field parameters (physiochemical data) using the surface water sampling field sheet.

   c) Lower the water quality meter sensors into the water until **all** sensors are submerged and record field parameters
   d) If further sampling is required, lower the water quality meter along with the dip meter to ensure target depth/s are accurately measured; record physiochemical data once stable
   e) Repeat step b) until the bottom of the surface water body or the specified sampling depth is reached.

   Limit any water disturbance while taking the surface water field parameters being careful to limit any excessive water mixing or sediment disturbance in the surface water body being sampled.

4.2.2 Telescopic Scoop Method

1. Be aware of surroundings as a fully extended scoop is approximately 4.0 m in length. When retrieving the sample, ensure that the rod is safely placed in an area and does not pose any trip hazard or accidentally pushes into a bee hive or an electric fence!
2. Ensure scoop has been decontaminated before use and sampling cup is firmly attached to the rod
3. Establish a safe sampling point
4. Extend scoop to required length (note: take care of the weight of the sample scoop which increases when the sampling cup is filled on the end of the fully extended - 4 m rod)
5. Rinse the scoop, downstream from intended sampling location, by simply dipping it into the water a couple of times. Discharge any excess water.

6. Lower scoop into water to required depth; if surface water body is flowing, sample upstream from operators sampling position (the scoop is not suitable for accurately sampling at various depths). Discharge the first sample of water from the scoop downstream from sampling point. Collect the water samples as required.
7. Retrieve the scoop and place surface water sample directly into the required sampling containers
8. Place samples into a chilled esky.
9. Decontaminate the scoop between each sample location

4.2.3 Van Dorn Sampler (VDS) Method

1. The VDS can be hired from Eco Environmental (Adelaide)
2. Ensure the VDS has been decontaminated before use
3. Ensure the rope is securely attached to the top (Purchase a new untreated cotton and/or nylon rope before each project to ensure cross contamination does not occur)
4. Place the rope through the 'messenger' and ensure it is securely attached
5. Establish safe sampling point
6. Set the VDS to its sampling set up, shown here in Table 1 and
7. Slowly lower the VDS into the water column allowing water to pass through the sampling chamber as it comes to rest horizontally at the sampling point (see Figure 2).
8. Release the messenger down the rope and retrieve VDS using the rope
9. Pour surface water sample from the 'taps' of the VDS directly into required sampling container and store in chilled esky

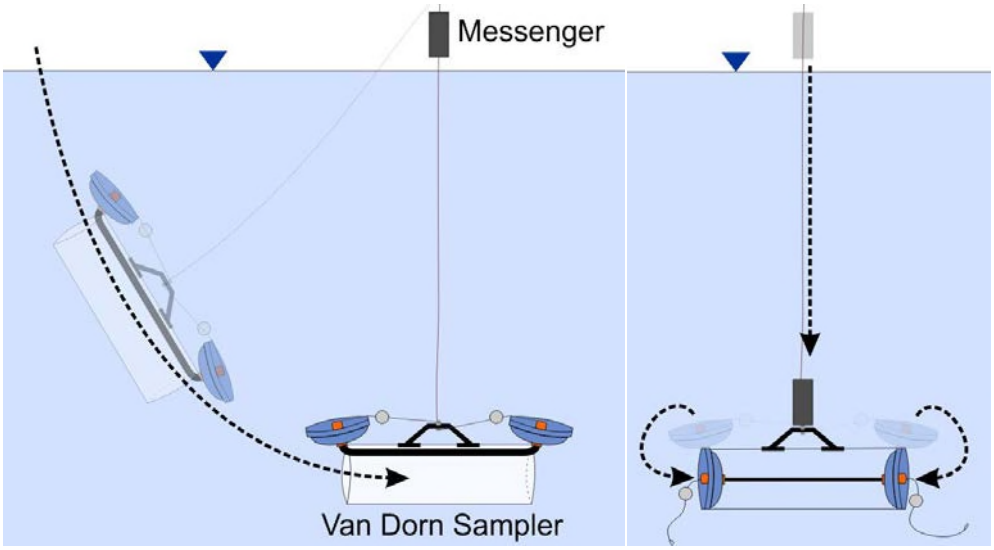


Figure 2: Surface Water Sampling using a Van Dorn Sampler

10. Decontaminate the VDS and all equipment that comes in contact with surface water between each sample location.

4.2.4 Direct Sample Collection Method

1. Ensure appropriate PPE is worn (e.g. long gloves, gum boots or waders)
2. Lower the lip of the sampling container below the surface water level upstream of body position. Unscrew sampling container under water and collect the respective samples
3. Transfer and slowly fill the respective sampling container and place cap on sample container once full (do not use a metals bottle for direct surface water sampling as the acid placed in the bottle can be displaced).
4. Place samples in a chilled esky.

4.3 Sample Quality Control and Quality Assurance:

4.3.1 Duplicates and Triplicates

A minimum of one duplicate and one triplicate sample shall be taken for every 20 primary samples collected (refer to SAP/WRF for site specific details). The duplicate and triplicate samples shall be collected as follows:

> A duplicate and triplicate sample should be collected at the same location as the primary sample at predetermined locations and/or locations where contamination is identified. Three samples from the one location aims to confirm the presence of contamination on the site and cross check the laboratory analysis program.

> Duplicates / triplicates should include blind and split samples taken immediately at the same time as the primary sample. Samples collected for duplicates, triplicates and laboratory duplicates should be filled at the same time and not one bottle at a time. Samples should be numbered to hide the identity of the primary sample.

> Three bottles are labelled (refer to naming below) and sample is evenly distributed over each jar.

> Each of the three bottles are filled to the top as quickly as possible to minimise the loss of VOCs without soils caught up in the thread and the jar cap is screwed on tight.

> The primary location where duplicate and triplicate sampling occurred is recorded on Cardno Lane Pipers QAQC record sheet.

> Additional duplicates and triplicate samples can be collected to further assess contaminated areas on the site. These samples can be placed on hold pending analysis of the primary sample.

> The duplicate sample shall be labelled QC01 or sequential numbering order for QC samples taken at that site, and shall also be entered on the F3.01 QC Sample Register and the F3.08 Surface Water Sampling Field Record, in the space provide for "Duplicate Reference".

> For large sites where multiple field crews are conducting work simultaneously a site specific QC register shall be prepared by the field or project manager so that each quality control sample is recorded correctly and uniquely (refer to site specific SAP/WRF).

Rinsates, Field Blanks and Trip Blanks.

Rinsates, Field Blanks and Trip Blanks allow for a high level of quality when sampling surface water in the field. Minimum requirements for control samples are subject to the specific requirements of the project (see SAP/WRF for site specific details) but as a minimum, they are as follows:

> **One rinsate** collected per day of a piece of equipment that is in regular contact with the samples. Eg a sample tube, the pump, a glove. A rinsate blank is used to check the effectiveness of re-useable equipment decontamination; therefore it can be undertaken at the end or close to the end of each day.

> **One rinsate** shall be collected in the sample bottles and filling them with de-ionised water supplied by the laboratory. The water is decantered over the appropriately selected piece of equipment. The bottles are filled to the top. The QA/QC sampling requirements should be taken from the WRF and SAP.

> **One field blank** is generally collected per day, but specifics depending on the sampling regime of the project (see SAP/WRF). A field blank shall be collected in the sample bottles and filled using de-ionised water supplied by the laboratory. The water is decantered into the bottles and filled to the top. A field blank is to assess the potential for contaminants in the laboratory water or in the ambient air in the vicinity of sampling to effect the results.

> **One trip blank** per esky. Trip blanks are supplied by the laboratory with the sample containers prior to the sampling event and are placed in the eskies. The trip blank is a control sample to check if that sample integrity is not lost during transit to the laboratory, particularly for the loss of volatile compounds.

> All QAQC samples discussed above are handled as follows:

- These samples are placed on ice and are should remain chilled from collection on site to delivery to the laboratory under chain of custody.
- Correctly recorded on the COC for analysis, refer to the SAP/WRF or PM for analysis requirements.
- Record the correct primary sampling and control details on a separate record sheet. F3.01 QC Sample Register

4.3.2 Equipment Decontamination

Decontamination is the process of neutralizing, washing, rinsing and removing material from exposed surfaces to minimise cross contamination of samples from sampling equipment.

As a minimum equipment such as low flow pumps, dip meters or grab samplers used to collect water samples shall be washed with biodegradable and phosphate free detergent and rinsed with tap and distilled water. Three buckets shall be set up prior to sampling to undertake this process as follows:

> Bucket 1: Filled with water and decon solution for washing and scrubbing (if required) field equipment in contact with samples

> Bucket 2: Filled with tap water to rinse equipment of detergent

> Bucket 3: Filled with distilled water to further rinse equipment of detergent

> Remove soil adhering to the sampling equipment. Then wash the equipment by scraping, brushing or wiping with a brush using water and decon bucket 1.

> Rinse thoroughly in Bucket 2 with tap water.

> Rinse thoroughly in Bucket 3 to remove detergents and dry with disposal towels.

> Repeat steps above between each bore/sampling location

4.4 Sample Handling & Preservation

Sample bottle labelling, preservation and storage shall be in accordance with Australian Standard AS2031.1 Preservation & Storage of Water Samples. Samples shall be preserved according to the requirements of testing for the analysis required, for example acid preservation, freezing etc. Appropriately pre-preserved sampling containers need to be obtained from the laboratory prior to the field mobilisation for the analytes required (as per the WRF and SAP).

4.5 CoC and Primary and Secondary Laboratories

Chain of Custody (CoC) forms are used for the purpose of certifying the integrity of samples between the time taken and when received at the laboratory. The COC is a legal document for transporting surface water samples and requesting analysis from the primary/secondary laboratory. The following sequence of actions and requirements shall be used to prepare separate COC forms F3.01 Chain of Custody for the primary and secondary laboratory when sending groundwater samples:

> At the completion of the sampling event (or day of sampling), the samples shall be removed from the Eskies and a check made that all sample bottles are present. These should then be checked against the bore location list to ensure that all locations have been sampled.

- Pack the samples bottles in the Eskys in an upright position and ensure that seals or caps are secured to prevent leakage. Pack the supplied freezer bricks evenly around the water samples. Ensure that samples are packed to prevent breakage during transport by using bubble wrap.
- The sample number, details of each container type to be placed in each Esky, location and depth of the sample, time of sampling, and details of the preservative added shall be entered onto a CoC Form.
- The address of the laboratory, phone number and contact person is completed on the COC.
- The analysis requested and which samples will be placed on HOLD. The correct laboratory codes for the analysis requested written next to the analysis requested. Specific project quote numbers or codes for specific analysis or special rates should also be included. This is information should be in the WRF and discussed with the PM on site. If this is not practical, samples on the COC can be placed on HOLD, with a supplementary COC sent within 24-48hours of the samples being sent.
- Correct names of the samples with the corresponding sample jars including all quality control samples are recorded.
- Field observations of strong odours or signs of contamination of particular samples are added on COC
- The requested turnaround times. Eg Standard (5 days), Fast tracked (3 days), Urgent (24 or 48 hrs). Turnaround times within 5 days require confirmation with the laboratory prior to the sampling.
- The names/signatures of the sampler and/or the person relinquishing the sample are added. The COC is signed by the courier picking up the samples (either from the office or in the field) is added.
- Secure the lids on the Eskies and tape the lids in place with packing tape.
- A copy of this signed COC form is kept as a record of dispatch to the laboratory and is placed inside the respective eskies in a plastic bag (such as a GLAD zip lock bag).

4.6 Field Notes & Fieldwork Requirements

- Attend a kick off meeting with the project manager or project associate
- Prepare a job safety analysis and/or HASP
- Confirm sample naming convention for the site
- Good on site practices and housekeeping (keep a tidy work area):
- Call into the PM or nominated buddy at the start and end of each day and for any expected events.
- The order of sampling locations is from up gradient/river or least contaminated location, moving closer to sample locations situated near source areas. The safety of staff and the practicality of undertaking sampling in this order takes precedence over sampling in this order (refer to SAP/WRF and discuss with PM).
- All sections of the field notes must be filled in out in the field and are legible for someone else to read and transfer electronically if required. The vehicle or site office on site can be used during periods of inclement weather.
- Refer to the waste management procedure for further guidance. As a minimum the field supervisor responsibility includes the following:
    - Safe and secure location of drums, skip bins or bulky bins to collect “waste” generated from field assessments. The location of drums should be confirmed with the PM.
    - Waste PPE, consumables such as bailers, gloves or tubing should be placed in drum on site and labelled correctly.

- All field notes should be scanned into the fieldwork folder at the conclusion of the fieldwork program.
- Data Quality Management requirements should be discussed with PM or team leader when results are received from the laboratory.

> Clean up and secure sampling location to conditions as found prior to sampling prior to leaving location.

Specific project requirements will be undertaken for transportation of samples due to varying analysis and holding times and this shall be confirmed and pre-arranged by the field supervisor with the PM prior to commencing work on the site.

F3.08 Surface Water Sampling Field Record

Site / Project:	**Page: _____ of _____**	
Client:	**Job No.:**	
Person Sampling:	**Initials:**	**Date:**

Site Details
Water Scoop / Van Dorn Sampler / Directly into bottle / Other:
Last rain event/ Recent storms/ Any unnatural releases/ Other:

Sample Details, Observations, GPS Coordinates & Field Physiochemical Measurements (if possible, record parameters once stable):				
Sample ID				
Time				
Sample Depth (m)				
Water Body Depth m				
Location On-Site/ Off-Site				
Flow Rate High/ Med./ Low				
GPS Zone (i.e. 55H)				
Easting mE				
Northing mN				
GPS Error ±m				
DO mg/L				
EC µS/Cm				
pH				
Eh mV				
Temp °C				
Water Colour				
Turbidity High/ Medium/ Low				
Observations/Notes				

Container & Preservation Data										
Container Volume										
Container Type	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial	Plastic/ Amber/ Vial
Preservation										
Sample ID (Inc. QC samples below)										

HEALTH SAFETY & ENVIRONMENT WORK METHOD STATEMENT (HSEWMS)

WMS NO.: V160382P **REVISION#:** 01.1

PREPARED DATE: 1 May 2020

PRINCIPAL CONTRACTOR: City of Darwin	**CONTRACTOR NAME:** Cardno
PROJECT NAME: SBWMF – Ground Water Monitoring	**CARDNO ADDRESS:** 93 Mitchell St, Level 6, Darwin, NT 0820
PROJECT LOCATION: Shoal Bay Waste Management Facility	**CARDNO ABN:** 47 106 610 913

JOB DESCRIPTION: Groundwater Monitoring Event (GME)

PLANNED HIGH RISK CONSTRUCTION ACTIVITY

☐ Confined Space Entry	☐ On/Near Energised Electrical Services	☐ Excavation Entry >1.5m	☐ Explosives Use	☐ Work On/Near Gas / Chem / Fuel / Refrigerant line
☒ On/in/near traffic corridor (e.g. road, rail, shipping)	☐ Mobile Plant Movement	☐ Diving Work	☐ Work on a roof	☐ Flammable / Contaminated Atmosphere
☐ Structural Alterations	☐ Tilt Up / Precast Use (Concrete)	☐ Fall from Heights >2m	☐ Work In / Over Water	☐ Artificial Extreme Temperature
☐ Disturbance of Asbestos	☐ Telecommunications Tower	☐ Demolition Work	☒ Hazardous Substances	☐ Asbestos/Demolition License No. -

PLANT AND EQUIPMENT REQUIRED FOR THIS ACTIVITY: Wide Brimmed Hat, Sunscreen, Digital Camera, Multi Parameter Probe, Dip Meter, Hydrasleeve Samplers

PERSONNEL TRAINING & QUALIFICATIONS REQUIRED FOR THIS ACTIVITY:

MSDS Required: Yes ☐ No ☒

d

Personal Protective Equipment Required



☒ ☒ ☒ ☒ ☒ ☐ ☒ ☐ ☒

Legislative Governance: This Work Method Statement is in compliance with the Australian Work Health and Safety Act 2011, in particular with sections 17, 20, 21, 22, and the Work Health and Safety Regulations 2011, in particular sections 299, 300, 301, 302, 303. (Please Refer to Local Legislation in VIC & W.A.)
For NZ the Health and Safety in Employment Act 1992 in particular section 7 (a)(b)(c), 8, 9 (a)(b) 10 (1)(2)(3)(4)(5)(6) and Health and Safety in Employment Regulations 1995 in particular section 4 (1)(2).

WMS DEVELOPED BY:

No	Name	Position	Date
1	David James	Project Director	1 May 2020
2	Julian Brown	Environmental Scientist	1 May 2020
3			

PERMITS

☐ Confined Space Entry	☐ Hot Work
☐ Electrical	☐ Working At Heights
☐ Guards Off	☐ Excavation
☐ Diving	

COPY OF SWMS SUPPLIED TO PRINCIPAL CONTRACTOR/CLIENT/CUSTOMER: APPROVAL: ☒ *(PC/Client/Customer USE ONLY BELOW)*

Name: Matthew Vitucci	**Signature:**	**Position:**	**Contact No.: 0429156860**	**Date:**

JOB DESCRIPTION:						WMS No.:V160382P		REVISION: 01.1
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
General Activities / Hazards								
1	**Transport to and from site**	Traffic and other road users	Impact with other vehicles or road users, injury/death. Damage to vehicle.	E22	• Drivers must hold a current, valid driver's license, knowledge of relevant road rules. • Driver to remain vigilant of other road users and respond to hazards appropriately and in accordance with road rules. • Trip planning – the route should be planned prior to commencing, including having a map of the planned route available. • First Aid kit to be kept in vehicle.	M12	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
		Obstructions / unexpected diversions	Impact with obstructions, other vehicles or road users, injury/death. Damage to vehicle.	E22	• Driver to remain vigilant of road conditions and obey all road rules, including temporary road signs/warnings.	M12	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
		Driver competence	Impact with other vehicles or road users, injury/death. Damage to vehicle.	E22	• Drivers must hold a current, valid driver's license, knowledge of relevant road rules.	M12	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
		Driver wellness (fatigue, drug and alcohol influence, physical state)	Impact with other vehicles or road users, injury/death. Damage to vehicle.	E22	• No person is to drive if under the influence of alcohol or drugs or if they are suffering from fatigue or have a physical impairment that may affect their ability to drive safely.	M12	Field staff (planning and preparation)	Project Manager Project Director

JOB DESCRIPTION:						WMS No.:V160382P	REVISION: 01.1	
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
					• Verbal communication, in person, is to be made with Project Manager or Supervisor. • Supervisor to ensure staff are not tired and their awareness and/or judgment have not been adversely affected by work activities, weather and/or other influencing factors. • Alcohol and drug testing may be enforced. • For long journeys frequent breaks should be taken (approx. every 2 hours) – driving should be shared where possible. • Vehicle to carry minimum of 10L of water per day.		PM/PD (training and works preparation)	Site supervisor / field Staff
		Inclement weather	Impact with other vehicles or road users, injury/death. Impact with flying debris/falling trees. Damage to vehicle.	E22	• Monitor BOM website and do not travel if weather conditions are considered to present too high hazard. • If the journey is undertaken driving style should be adapted appropriately in accordance with the conditions.	M12	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
2	**Site housekeeping**	Poor housekeeping Excessive tools, materials and equipment in the work area Obstructed walkways / roads Uneven ground / trip hazards	Slips, trips and falls. Other injury. Damage to equipment.	H17	• Complete Safety STOP (aka SLAM, Take 5) prior to assess hazards in work area • Conduct pre-site checks, clear work area of debris, excess tools and materials, litter etc. • Stack and/or store materials and equipment in approved lay down areas off the ground. • Clean and tidy area as work progresses.	M9	Site supervisor / field staff (fieldwork) PM/PD (training and preparation)	Project Manager Project Director Site supervisor / field Staff

JOB DESCRIPTION:						WMS No.:V160382P	REVISION: 01.1	
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
					• Ensure all open penetrations are barricaded /signposted prior to leaving the work area. • Remove all excess waste after each task and place in receptacles provided, follow posted waste segregation signage.			
3	**Manual handling**	Heavy lifts / dropped objects	Injury from heavy lifts / dropped objects, damage to muscles and soft tissue, bruises, scrapes.	H14	• No single person unaided lift of objects > 25 kg. • Mechanical lifting/transport aid where possible. • Two man lift if safe to do so for heavy/awkward objects (25kg or more) where mechanical lift is not practical. • Appropriate gloves to be worn for all tasks. • Manual handling training to be provided (i.e. “safe spine, bend knees not back”). • Conduct stretch and flex exercises after pre-starts, and after breaks if necessary.	M6	Site supervisor / field staff (fieldwork) PM/PD (training and preparation)	Project Manager Project Director Site supervisor / field Staff
4	**Workforce skills**	Unskilled workers Insufficient training Level of job knowledge	Injury caused by inappropriate use of tools or equipment, or by not adhering to site rules / task rules and procedures	H19	• Stop work authority in place. • Tool box talk to be undertaken prior to the works commencing and at the start of each day. • Mandatory PPE to be worn at all times. • Daily equipment pre-start inspections. • Ensure that all stakeholders are informed of works. • During the period of the project, staff that either change position or join the project must be assessed against the project training needs	M12	Site Supervisor / field staff (assessment of contractors) PM/PD (training and preparation)	Project Manager Project Director Site supervisor / field Staff

#	Job Step *Describe the job by step*	Hazard *What are the hazards of each step?*	Possible Consequences *What are the possible injury/incident consequences of each step?*	Risk Rating *Use the Risk Matrix to give an initial rating*	Control Methods to be Implemented *What control measures will be used?*	Residual Risk Rating *Use the Risk Matrix to give a residual risk rating*	Responsible Person	Monitor & Review
					to ensure all specific H&S training needs are met. • Ensure compliance with requirements identified by the SWMS.			
5	**Monitoring of tasks and procedures**	Ineffective control measures implemented and/or not being used properly	Injury, incident, damage to equipment	H14	• Obtain Work Permit(s) from Central Control Room prior to commencement of tasks. • Obtain gas pre-clearance and hot works permit prior to undertaking works in ammonia plant area. (Incl. continues monitoring). • PLAN - DO – CHECK – ACT. • Stop work immediately if any additional hazards have been identified and review SWMS. • Advise each person affected by any amendment to the SWMS and the details of the amendment, have safety review and sign. • Consult with supervisors and workers, regarding any ineffective control measures, stop work until corrected. • Daily work place inspections.	M9	Site supervisor / field staff (monitoring of procedures) PM/PD (training and preparation)	Project Manager Project Director Site supervisor / field Staff
6	**Environmental**	Ultraviolet light	Sunburn, sunstroke, long-term UV effects	E24	• Avoid sun exposure wherever possible. • Apply a broad spectrum sun screen =>30+ every 2hrs. • Take shaded rest breaks. • Wear a hard hat brim. • Long sleeves to be rolled down and buttoned.	M8	Field staff (planning and preparation) PM/PD (training, PPE and works preparation)	Project Manager Project Director Site supervisor / field Staff

#	Job Step *Describe the job by step*	Hazard *What are the hazards of each step?*	Possible Consequences *What are the possible injury/incident consequences of each step?*	Risk Rating *Use the Risk Matrix to give an initial rating*	Control Methods to be Implemented *What control measures will be used?*	Residual Risk Rating *Use the Risk Matrix to give a residual risk rating*	Responsible Person	Monitor & Review
		Excessive temperatures	Dehydration	E24	• Drink plenty of water and take regular meal breaks. • Work in shaded areas where possible. • Air condition containers, cabins and/or site vehicles. • Regular rest breaks in cooler shaded areas. • Supervisor to monitor work crew and look after your mates. • Store chemicals out of direct sunlight, in proper cabinets where required. • Ensure adequate potable drinking water is available. • Implement the Cardno Heat Stress Protocol (see attached).	M8	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
		Environmental incident: 1. Disturbance of flora and fauna. 2. Spillages. 3. Air quality. 4. Interaction with snakes, spiders and other fauna.	Environmental incident, damage to the environment, personal injury	H18	• Regular inspections & maintenance to be carried out on tools, plant and equipment. • Avoid interaction with fauna – Stop Work Authority, contact supervisor/project manager, monitor risk/hazard if safe to do so. • Trained first aiders on work site. • Personnel to be familiar with emergency response procedures, hold toolbox meeting with crew. • Environmental incidents to be reported to appropriate persons where required. (in the event of incident CSPB has in house emergency response team, call 84118444)	9M	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
		Contaminated waste / water	Contamination of “clean” soil/water	H14	• Water to be placed into appropriate containers for temporary storage prior to classification and appropriate transport/disposal.	M6	Field staff (planning and preparation)	Project Manager Project Director

JOB DESCRIPTION:						WMS No.:V160382P	REVISION: 01.1	
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
					• Storage containers should be securely closed, clearly labelled, and positioned such that they are unlikely to be disturbed by other site activities. • Site supervisor and/or client to be informed of their location and content.		PM/PD (training and works preparation)	Site supervisor / field Staff
		Inclement weather	Injury, environmental incident	H19	• Monitor BOM website pre-mobilization and advise work crew of any potential hazards/restrictions/control methods. • Stop Work Authority in place.	M9	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
7	**Use of PPE**	PPE not suitable/inadequate for tasks being undertaken	Injury (slip, trip, fall, dropped objects, cuts, impact, traps)	E22	• Check PPE prior to works. • Ensure PPE is serviceable and correctly fitted. • Ensure clothing is fitted correctly (loose clothing has the potential to be drawn into the moving parts of machinery). • Shirts must be buttoned to at least the 3rd button from the top of the shirt • Sleeves must be rolled down and buttoned.	M9	Field staff (planning and preparation) PM/PD (training, PPE and works preparation)	Project Manager Project Director Site supervisor / field Staff
8	**Noise**	Excessive noise	Impaired hearing	H18	• Follow mandatory safety signage and use appropriate hearing protection as required by site requirements. • Where exposure to excessive noise cannot be avoided personnel will wear appropriate hearing protection.	M9	Field staff (planning and preparation) PM/PD (training, PPE and works preparation)	Project Manager Project Director Site supervisor / field Staff

JOB DESCRIPTION:						WMS No.:V160382P	REVISION: 01.1	
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
• **Job Step Activities / Hazards**								
A	**Traversing the site by foot**	Slopes, uneven ground, wet ground	Injury from slips, trips and falls.	H17	• Obtain Work Permit(s) from Central Control Room prior to commencement of tasks • Obtain gas pre-clearance and hot works permit prior to undertaking works in ammonia plant area. (Incl. continues monitoring). • Personnel should plan route across the site, keeping to pedestrian tracks/pathways where possible. • Personnel should be aware of the environment that is around them and ensure that solid footing is kept at all times. • PPE including steel capped boots should be worn to prevent injury in the event of a trip, slip or fall.	M9	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
B	**Driving light vehicle across site**	Site traffic and other site users. Members of the public / trespassers. Fatigue. Soft or uneven ground, or obstructions.	Incident, injury, damage to vehicle or infrastructure	E22	• Obtain Work Permit(s) from Central Control Room prior to commencement of tasks • Obtain gas pre-clearance and hot works permit prior to undertaking works in ammonia plant area. (incl. continues monitoring) • Drivers must hold a current, valid driver's license, knowledge of relevant site/road rules. • Hazard lights to be used. • Speed to be kept to < 15 kph unless other site speed limits apply.	M10	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff

#	Job Step *Describe the job by step*	Hazard *What are the hazards of each step?*	Possible Consequences *What are the possible injury/incident consequences of each step?*	Risk Rating *Use the Risk Matrix to give an initial rating*	Control Methods to be Implemented *What control measures will be used?*	Residual Risk Rating *Use the Risk Matrix to give a residual risk rating*	Responsible Person	Monitor & Review
					• The route should be planned, keeping to vehicle tracks where possible, and avoiding areas of soft or uneven ground to avoid bogging or tipping. • No person is to drive if under the influence of alcohol or drugs or if they are suffering from fatigue or have a physical impairment that may affect their ability to drive safely. • Verbal communication, in person, is to be made with Project Manager or Supervisor. • Supervisor to ensure staff are not tired and their awareness and/or judgment have not been adversely affected by work activities, weather and/or other influencing factors. • Alcohol and drug testing may be enforced.			
C	**Changing Tyre**	Raised Vehicle, Muscular stress, falling objects, damage to equipment	Injury, incident, damage to vehicle.	E22	• Isolate vehicle • Ensure vehicle is in gear, with handbrake on, wheels choked. • Ensure Jack is stable and at correct jacking point (see vehicle manual). • Do not over exert, causing muscle strain. • Use correct lifting and manual handling techniques, eg. Bend knees with straight back. Roll tyre where possible. • Keep everything clear from beneath vehicle when jack in use.	M10	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff

JOB DESCRIPTION:				WMS No.:V160382P		REVISION: 01.1		
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
					• Insert spare wheel under axel, to provide extra support when vehicle is jacked. • Re-check wheel-nut tightness.			
G	**Groundwater development / monitoring / sampling**	Liquid spray. Exposure to contaminated groundwater.	Injury, exposure to hazardous chemicals	H17	• Personnel will be required to wear PPE appropriate to the conditions at the site in order to avoid contact with chemicals that may be present in the groundwater at the site (i.e. safety glasses, nitrile gloves etc.	M9	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff
D	**Survey Bore headworks / TOC / Ground level**	Exposure to contaminated groundwater. Explosive atmosphere Fauna / Flora Interaction	Injury, incident, damage to vehicle or infrastructure, exposure to hazardous chemicals	E22	• Obtain Work Permit(s) from Central Control Room prior to commencement of tasks • Obtain gas pre-clearance and hot works permit prior to undertaking works in ammonia plant area. (incl. continues monitoring) • Personnel will be required to wear PPE appropriate to the conditions at the site in order to avoid contact with chemicals that may be present in the groundwater at the site (i.e. safety glasses, nitrile gloves etc. • Follow mandatory safety signage and use appropriate hearing protection as required by site requirements. • Avoid interaction with fauna – Stop Work Authority, contact supervisor/project manager,	M12	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff

JOB DESCRIPTION:						WMS No.:V160382P		REVISION: 01.1
#	**Job Step** *Describe the job by step*	**Hazard** *What are the hazards of each step?*	**Possible Consequences** *What are the possible injury/incident consequences of each step?*	**Risk Rating** *Use the Risk Matrix to give an initial rating*	**Control Methods to be Implemented** *What control measures will be used?*	**Residual Risk Rating** *Use the Risk Matrix to give a residual risk rating*	**Responsible Person**	**Monitor & Review**
					monitor risk/hazard if safe to do so.			
G	**Groundwater Water Level monitoring**	Liquid spray. Exposure to contaminated groundwater.	Injury, exposure to hazardous chemicals	H17	• Personnel will be required to wear PPE appropriate to the conditions at the site in order to avoid contact with chemicals that may be present in the groundwater at the site (i.e. safety glasses, nitrile gloves etc.	M9	Field staff (planning and preparation) PM/PD (training and works preparation)	Project Manager Project Director Site supervisor / field Staff

Sign-Off Sheet

All persons performing any activity covered by this WMS MUST sign off prior to commencement of this task as recognition of having read and understood the work steps and preventative actions required to reduce the risk of harm, and ensure safe work practices are maintained.
I, the undersigned declare that I have read and understand the requirements of this WMS and will work in accordance with the prescribed controls.

Name	*Signature*	*Position*	*Date*	*Name*	*Signature*	*Position*	*Date*
[]	[]	[]	[]	[]	[]	[]	[]
[]	[]	[]	[]	[]	[]	[]	[]
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LIKELIHOOD OR FREQUENCY (How much chance is there of It happening)	CONSEQUENCE SEVERITY				
	1 INSIGNIFICANT	2 MINOR	3 MODERATE	4 MAJOR	5 CATASTROHPIC
A – Almost Certain	Moderate 11	High 16	Extreme 20	Extreme 23	Extreme 25
B - Likely	Moderate 7	High 13	High 17	Extreme 21	Extreme 24
C - Possible	Moderate 5	Moderate 8	High 14	High 18	Extreme 22
D - Unlikely	Low 2	Low 4	Moderate 9	High 15	High 19
E - Rare	Low 1	Low 3	Moderate 6	Moderate 10	Moderate 12

E = Extreme Risk	Immediate action required to implement better controls. Activity must not start or be stopped if started. Senior Management to give approval for work to commence or continue.
H = High Risk	Immediate manager to give approval for work to commence or continue. More suitable controls to be investigated.
M = Moderate Risk	Work to proceed once risk is reduced to as low as reasonably practicable and controls are implemented.
L = Low Risk	Work to proceed while monitoring and managing risk.

QUALITATIVE MEASURES OF IMPACT – CONSEQUENCE

LEVEL	IMPACT	EXAMPLE OF CONSEQUENCE
1	Insignificant	No injuries; no environmental impact.
2	Minor	First Aid; environmental release immediately contained.
3	Moderate	Medical Treatment; environmental release not immediately contained with no detrimental effects.
4	Major	Lost Time Injury/Illness; environmental release not immediately contained with toxic effects.
5	Catastrophic	Fatality; release to the environment with long term/permanent toxic effects.

QUALITATIVE MEASURES OF LIKELIHOOD

Step 1

Determine the **consequence** : What do you perceive as the likely outcome or loss if the hazard were not managed appropriately? To assist with this component, you may wish to consult with others from the area or activity and review previous safety performance data.

LEVEL	MEASURE	DESCRIPTION	GUIDE
A	Almost Certain	The event is expected to occur in most circumstances	Once or several times a day
B	Likely	Will probably occur in most circumstances	Once per week
C	Possible	Might occur at some time	Once per month
D	Unlikely	Could occur at some time	Once per year
E	Rare	May occur only in exceptional circumstances	May occur once per ten years

Step 2

Determine the **likelihood** : How likely do you perceive an incident would result if the hazard were not managed appropriately? To assist with this component, you may wish to consult with others from the area or activity and review previous safety performance data.

Step 3

Determine the **risk rating** : Match up your consequence rating and likelihood rating. You should end up with either a low, moderate, high or extreme risk rating.

Hazard Control Prompts

most effective

Elimination	Can we get rid of it altogether? e.g. doing the at ground level rather than at height eliminates falls from height risk.
Substitution	Can we find a process / substance etc less hazardous? e.g. use of less toxic solvents.
Isolation	Can we put something between the hazard and people? e.g. install guarding and handrails.
Administrative	What can we tell, show people about safety? e.g. training, safe work procedures.
PPE	What can people wear that will reduce either the probability or the consequence of something happening?

least effective

Hazard Prompts

General:	• Struck by • Strike against • Caught in / between • Slips, trips • Falls on same level • Falls from height • Manual Handling • Visibility • People/pedestrians
Energy Source: (Contact with)	• Electricity • Mechanical • Pressure • Chemical • Other
Exposure to:	• Dust • Noise • Fumes • Heat • UV • Wet conditions • Animals

Shoal Bay Waste Management Facility

Water quality monitoring data review 2016 - 2020

Report prepared for City of Darwin



www.ecoz.com.au

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Recipients are responsible for eliminating all superseded documents in their possession.

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Appendices

APPENDIX A STANDARD OPERATING PROCEDURE, SHOAL BAY WASTE DISPOSAL SITE, WATER MONITORING

APPENDIX B WATER QUALITY TREND ANALYSIS GRAPHS

ACRONYMS AND ABBREVIATIONS

ANZECC	Australian and New Zealand Environment and Conservation Council
BOD	biochemical oxygen demand
BoM	Bureau of Meteorology
BTEXN	benzene, toluene, ethylbenzene, xylene, naphthalene
Chl-a	chlorophyll a
CoD	City of Darwin
COD	chemical oxygen demand
DO	dissolved oxygen
EC	electrical conductivity
EPL	Environment Protection Licence
FRP	filterable reactive phosphorus
L/N	ratio of ions associated with leachate to ions associated with natural groundwater
NATA	National Association of Testing Authorities
NH_3	ammonia
NH_3 as N	total concentration of nitrogen as ammonia in all forms (NH_3 and NH_4^+)
NH_4^+	ammonium ion
NOx	nitrate NO_3 + nitrite NO_2
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
PAH	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
pH	power of hydrogen
PFAS	per and poly-fluoroalkyl substances
PFBA	perfluorobutanoic acid (
PFBS	perfluorobutane sulfonic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
RDX	cyclotrimethylenetrinitramine (type of explosive)
SBWMF	Shoal Bay Waste Management Facility
SO_4	sulfate
SOP	standard operating procedure
SSTV	site specific trigger value
SWL	standing water level
TDS	total dissolved solids
TN	total nitrogen
TNT	trinitramine (type of explosive)
TOC	total organic content
TON	total organic nitrogen
TP	Total phosphorus
TSS	total suspended solids
TP	total phosphorus

TPH/TRH	total petroleum hydrocarbons/total recoverable hydrocarbons
VFA	Volatile acids as acetic acid
WMPC Act	Northern Territory *Waste Management and Pollution Control Act*

1 INTRODUCTION

City of Darwin (CoD) operate the Shoal Bay Waste Management Facility (SBWMF) located approximately 12 km north-east of Darwin city (Figure 1-1). This facility is the main municipal waste resource recovery and disposal site servicing domestic and commercial customers in the Darwin area.

Water quality monitoring is undertaken on a regular basis (predominantly monthly) at the SBWMF, to detect if contaminants from the landfills, or associated operations, are present in groundwater or surface water. CoD engaged EcOz Environmental Consultants (EcOz) to review all data collected as part of the SBWMF water quality monitoring program since its inception in July 2016 to the present (March 2020). The aim of this review is to characterise the groundwater, surface water and landfill leachate quality across the site, including any seasonal trends. This can in turn can help identify and assess any water quality concerns, and inform water management measures for minimising any potential offsite environmental impacts.

1.1 Purpose

The SBWMF is licenced to receive and manage waste in accordance with Environment Protection Licence 188 (EPL188) issued by the Northern Territory Environment Protection Authority (NT EPA) under the *NT Waste Management and Pollution Control Act* (*WMPC Act*). As per EPL188 and the *WMPC Act*, CoD has a duty to not cause environmental harm and to minimise any offsite impacts from the facility to groundwater aquifers, natural surface water bodies, natural ecosystems, or users of groundwater or surface waters downstream. Of particular importance, is to prevent the migration of leachate from landfill cells into groundwater aquifers or surface water bodies that then flow offsite.

Groundwater, surface water and landfill leachate water quality monitoring is undertaken across the SBWMF in accordance with the conditions of EPL188 and the *Shoal Bay Disposal Site Water Monitoring Plan* (URS 2016a). In regards to water monitoring results, the NT EPA must be notified of any contaminant concentrations exceeding the criteria specified in Condition 62 of EPL188 (i.e. 'non-conformances'), and the risk of any potential environmental harm assessed. A Monitoring Report must also be prepared annually, that presents all water quality monitoring data for the previous 12-months and assesses any potential environmental impacts from the facility.

This water quality monitoring data review, covering the period July 2016 – March 2020, is not a specific requirement of EPL188, but the information gained can be used as a basis for assessing potential environmental impacts in any future non-conformance notifications, and when preparing annual Monitoring Reports. It can also assist in informing water management measures at the facility in continuing to comply with the water quality criteria specified in Condition 62 of EPL188.

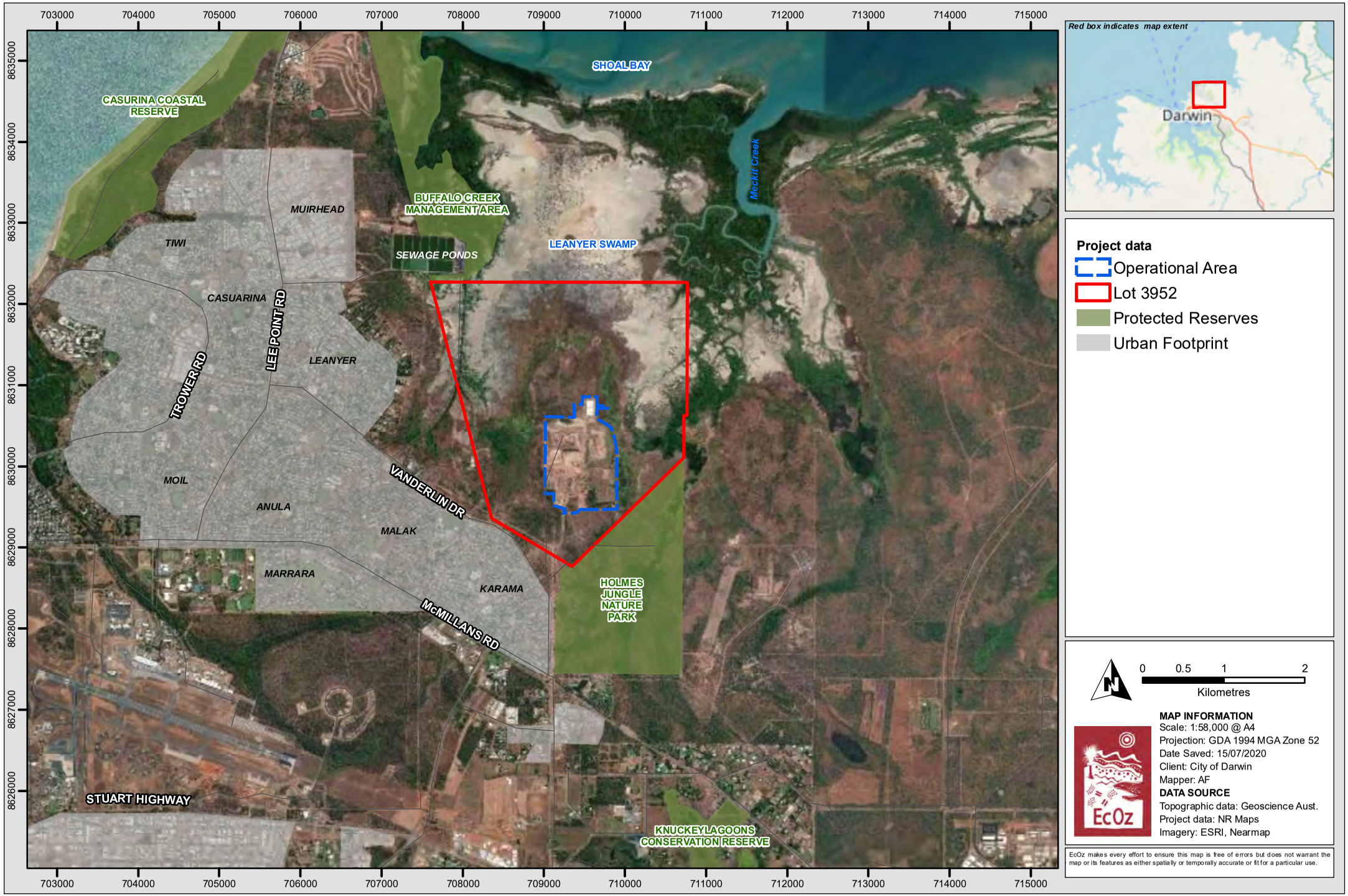
This review also considers how the monitoring program design (parameters measured, frequency of sampling, sampling sites etc.) could be better streamlined and targeted towards detecting water quality impacts at an early stage. Any changes to the monitoring program would require submission of an updated Water Quality Monitoring Program and amendment to EPL188 approved by the NT EPA.

1.2 Scope

This water quality monitoring data review has been developed to achieve the following:

- Summarise the leachate, surface water and groundwater monitoring activities undertaken from July 2016 – March 2020;
- Analyse the monitoring data and highlight the trends occurring for the three water types (leachate, surface water and groundwater), with particular consideration for indications of leachate ingress, or deteriorating water quality in certain areas of SBWMF;
- Discuss the potential environmental impacts to surface water and groundwater, and receiving offsite environments;

- Discuss the implications of these water quality monitoring results for improving water and leachate management at the SBWMF, and
- Review the on-going water quality monitoring program and suggest improvements.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig 1-1. SBWMF location.mxd

Figure 1-1. Map of SBWMF location

2 SBWMF OPERATIONS

The SBWMF lies within Lot 3952, Town of Sanderson (red boundary in Figure 1-1). CoD lease the entire property area from the Commonwealth Department of Defence. Under the terms and conditions of the lease, the property is designated as a Waste Management Project Area in which CoD is authorised to conduct waste management and ancillary activities.

The SBWMF is currently licenced under EPL188 to accept putrescible waste (commercial and domestic), green waste, and construction and demolition waste. More specifically, the facility is licenced to accept the following wastes, which are classified as 'listed wastes' under the NT *WMPC Act*:

- Animal effluent and residues
- Asbestos
- Clinical and related wastes
- Sewerage sludge and residues including nightsoil and septic tank sludge
- Soils contaminated with a listed waste
- Tyres.

The SBWMF also accepts the following 'listed wastes' for storage and subsequent collection by external operators for resource recovery/disposal at external facilities:

- Acidic solutions or acids in solid form
- Lead, lead compounds
- Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish
- Waste mineral oils unfit for their original use
- Domestic batteries
- Empty domestic gas bottles
- Domestic paint and chemical containers
- Fluorescent tubes.

Other materials accepted for storage and subsequent collection by external parties for resource recovery/disposal include:

- Green waste (accepted from domestic and commercial customers, mulched/processed on-site, then sold to the public)
- Metal
- Plastic containers
- Paper and cardboard.

Figure 2-1 provides a general site layout, which includes the currently used putrescible waste landfill cell (Stage 5), inert waste landfill cell (Stage 2), waste transfer station, recycle shop, mulching/processing facility for green waste, leachate management system and landfill gas management system.

The Stages 3 and 4 putrescible waste landfill cells reached capacity and were capped with interim capping in 2016/2017 (final capping is currently in the design stage). The Stage 5 cell is expected to reach capacity soon (early 2021) after which the waste will go to the Stage 6 landfill cells currently under construction.

The Stage 3, 4, and 5 landfill cells are lined and have a leachate collection system. The leachate collected is irrigated back onto the cells, when possible. Leachate storage ponds store excess leachate until it can be applied back onto the landfill cells.

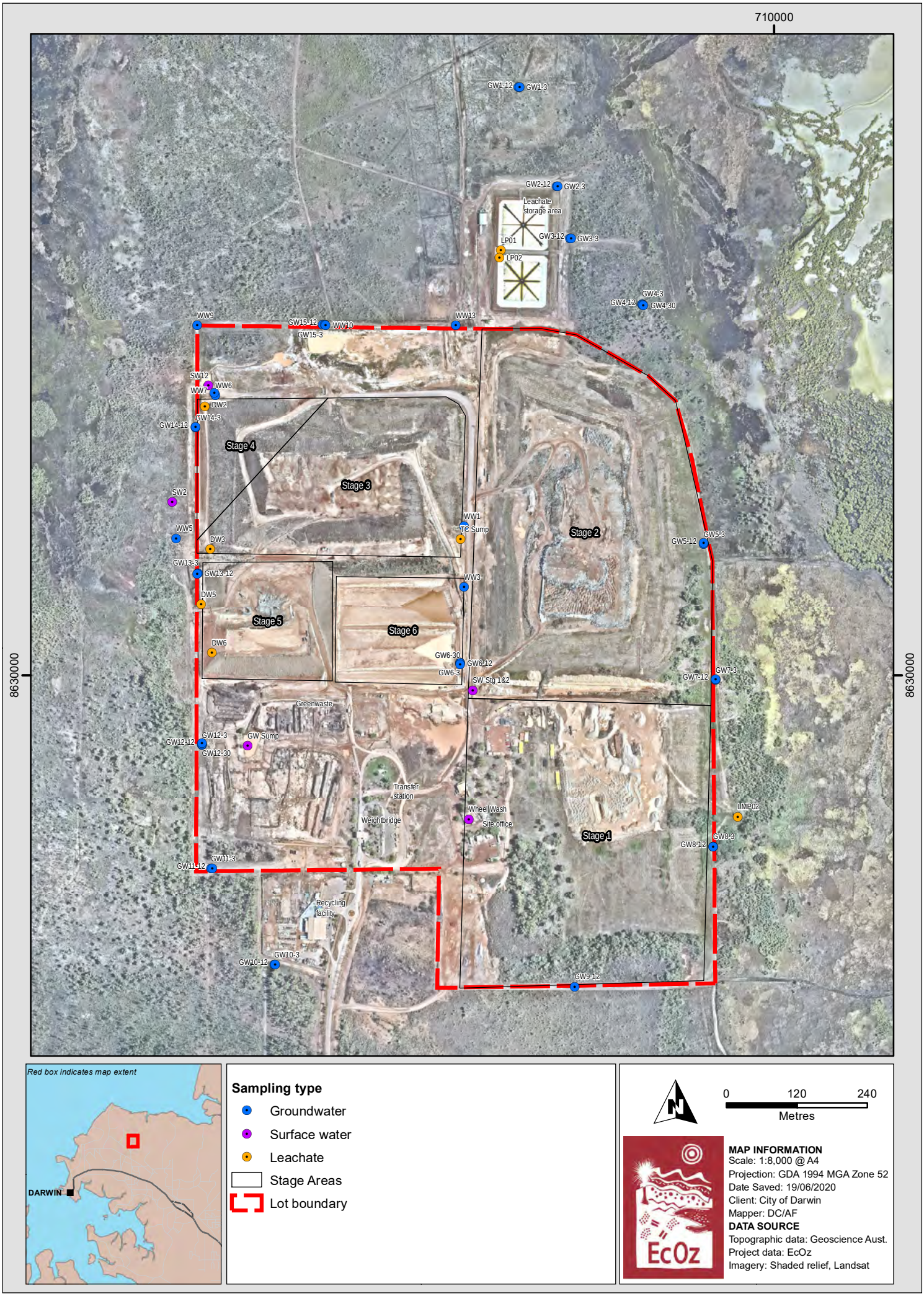
Stage 2 (north-east) is unlined and accepts inert waste (construction and demolition including asbestos). Stage 1 (south-east) is a historic unlined landfill, which is capped and not in use. Leachate from the unlined Stage 1 and 2 landfill cells is intercepted in an underground drain running north-south along the eastern edge of the cells. This then drains into a collection chamber 'LMP02', where it is pumped out and irrigated onto the capped Stage 1 cell.

Green waste storage and mulching occurs on a pad south of Stage 5.

A facility for the short-term storage of chemicals is located at the southern end of the site, within the transfer station.

Renewable energy is generated on site using landfill gas (methane) and provided to Darwin's power grid. The landfill gas management system involves capturing methane gas emissions from the landfill via a gas extraction system comprising vertical and horizontal wells drilled into the waste cells connected to a reticulation system. Condensate from the gas extraction system is pumped to disposal trenches within the Stage 2 landfill.

For more detail on the disposal, storage and handling of different waste types refer to the SBWMF *Environmental Management Plan* (CoD 2016), Sections 5.4 and 5.5, and for more detail on landfill leachate management and gas management, refer to the SBWMF *Environmental Management Plan* (CoD 2016), Section 5.6 *Water Quality Management* and Figure A5.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20036 - Shoalbay Water Monitoring 2020-2021\01 Project Files\Figure 2-1. Monitoring site locations.mxd

Figure 2-1. Map of SBWMF layout and sampling site locations.

3 ENVIRONMENTAL SETTING

3.1 Climate

The regional climate is tropical monsoonal with a distinct wet season (Nov-April) and dry season (May-Oct). Average yearly rainfall is 1,723 mm, with most of this (around 80%) occurring between December and March; taken from the nearest Bureau of Meteorology (BoM) Station with consistent long-term data, Darwin Airport No. 14015.

Rainfall during the period covered by this review (July 2016 - March 2020) is outlined in Section 5 below.

3.2 Surrounding land use

The SBWMF is surrounded by bushland, floodplains, wetlands and mangroves to the north, east and west (Figure 1-1). The Holmes Jungle Nature Park is located to the south. The nearest residential area to the SBWMF is the suburb of Karama, about 1 km to the south-west with a bushland buffer in between.

3.3 Surface water flows

Surface water from the eastern portions of the SBWMF flows towards the Meckitt Creek floodplain (Figure 1-1). Flows from the western portion of the site are towards the Leanyer Swamp and Buffalo Creek. Both Meckitt Creek and Buffalo Creek are mangrove-lined tidal inlets of Shoal Bay; a coastal embayment with extensive sand and mud flats (Figure 1-1).

For more detail on surface water flows and water management across the site, refer to the SBWMP *Environmental Management Plan* (CoD 2016), Section 5.6 *Water Quality Management*.

3.4 Groundwater

Groundwater aquifers beneath the site are described in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015). Lithology encountered during groundwater bore drilling for the investigation comprised top soils (silts and clays), generally underlain by weathered (lateritised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9 to 20 m below the surface across most of the site. Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock. Bore yields are generally very poor; less than 5 L/sec.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. Seasonal groundwater standing water levels (SWLs), measured as part of the SBWMF water quality monitoring program since 2016, are greater than 12 m below ground level at the end of the dry season, and usually less than 2 m from the ground surface during the peak of the wet season (see Section 6 below for more detail).

Groundwater down gradient of the SBWMF is saline due to its close proximity to the coast and tidal saline intrusion; see the *Groundwater Resources of the Darwin Area* map (DIPE 2003). There are no groundwater bores or groundwater users down gradient of the SBWMF; although an important environmental consideration is the supply of groundwater seepage into wetlands and tidal inlets during the dry season.

Higher yielding weathered and fractured carbonate rock aquifers occur in the wider region, with yields commonly greater than 5 L/sec. The *Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region* map (NRETA 2008) identifies a high yielding carbonate aquifer south-east of the SBWMF, trending in a northerly direction. Groundwater from this aquifer discharges to the surface within the Holmes Jungle Nature Park and maintains streamflow through the dry season. This spring and associated shallow groundwater support the Holmes Jungle rainforest. Further to the south-east around the Knuckey Lagoon

area, a large number of bores draw groundwater from this carbonate aquifer for domestic and agricultural purposes.

The carbonate rock aquifer and associated springs, Holmes Jungle rainforest and groundwater users are all located up gradient of the SBWMF. No significant areas of carbonate rock aquifer are located down gradient of the SBWMF and no carbonate rocks were encountered when drilling the 32 groundwater bores, to depths of up to 30 m below ground level, across the site for the hydrogeological investigation (URS 2015).

For detailed analysis of potential contamination pathways for leachate and other pollutants from the SBWMF towards potential human health and environmental receptors see the *Shoal Bay Waste Disposal Site Conceptual Site Model* (URS 2016b).

3.5 Environmental values

EPL188 lists the following 'Environment Protection Objectives' (Part 4 of the *WMPC Act*), 'Beneficial Uses and Water Quality Standards' (section 73 of the NT *Water Act*) and 'environmental interests' that apply to the site and surrounding areas:

- *Declared Beneficial Uses for the Darwin Harbour Area: Water Quality Objectives*, NTG Gazette 27, July 2010; these include the beneficial uses of: environment, agriculture, cultural and rural stock and domestic. Of these, the 'environmental' beneficial use is the stringent in regards to water quality requirements given aquatic organisms are the most sensitive of these beneficial uses to water quality changes.
- *Darwin Harbour Site of Conservation Significance (SOC 6)*

Shoal Bay and its associated shoreline tidal habitats and inland freshwater habitats have ecological values, as well as cultural and recreational values (e.g. fishing).

The SBWMF lies within the *Shoal Bay Site of Conservation Significance* (SOC 8); see Factsheet available on the *NT Government information and services* website: https://nt.gov.au/environment/environment-data-maps/important-biodiversity-conservation-sites/conservation-significance-list

An ecological risk assessment was undertaken for the SBWMF in 2016 that assessed the potential for ecological receptors to be impacted by contaminants from the site (see URS 2016c). The assessment included a survey of ecological values at three outfall sites: Stage 1 leachate pump outfall (LMP02), Stage 3 drain (SW2) and the Green Waste Sump (GW Sump), where it overflows offsite. The survey found that the immediate SBWMF surrounds are heavily infested with introduced weeds and the native habitats around each of the outfall areas does not provide optimum habitat for threatened species.

4 MONITORING UNDERTAKEN

4.1 SBWMF water monitoring program

Groundwater, surface water and leachate water quality monitoring has been undertaken at the SBWMF as per the URS (2016a) Water Monitoring Plan since July 2016, when EPL188 was issued. The water monitoring program design was informed by the conceptual site model (URS 2016b), which identified potential contaminant sources (i.e. landfill leachate, green waste leachate and other potential sources), potential contaminant pathways (into groundwater and surface water) and potential receptors (such as wetland habitats down-gradient of the site, groundwater users, and on site personnel). The aims of the water monitoring program, as specified in URS (2016a), are to:

- Determine baseline environmental conditions
- Monitor leachate production and composition
- Determine the effects on the environment due to the landfill on groundwater and surface water
- Check compliance with regulatory requirements
- Identify the need for remedial/mitigation measures.

The sections below outline the water monitoring program sampling methods, monitoring sites, sampling frequency, physical and chemical parameters measured, and assessment criteria applied to monitoring results.

4.2 Sampling methods

Throughout the period June 2016 to March 2020, CoD commissioned EcOz Environmental Consultants (EcOz), assisted by Larrakia Nation Rangers, to carry out the monitoring program. EcOz developed a specific standard operating procedure (SOP) for the SBWMF (provided as Appendix A), which is always followed. This SOP aims to ensure that samples are collected in a consistent, quality controlled, and safe manner, and follow best-practice procedures in accordance with the relevant standards and guidelines. This SOP also aims to ensure all monitoring information requirements of EPL188 are recorded and retained i.e. those outlined in EPL188 Condition 54. Please refer to the SOP for all specifics relating to sampling procedures.

4.3 Monitoring sites

Monitoring sites routinely sampled since July 2016, include 40 groundwater bores, 5 surface water sites and up to 8 leachate sites (originally 6 sites, then 2 additional sites related to Stage 5 landfill were added in June and November 2019 respectively). Figure 2-1 shows monitoring site locations. These sites include all those, as per the URS (2016a) Water Monitoring Plan, with some minor alterations and additional sites; as noted in Sections 4.3.1 to 4.3.3 below.

4.3.1 Groundwater monitoring bores

The 40 groundwater monitoring bores are detailed in Table 4-1. This bore network aims to allow detection of landfill leachate, or other contaminants, migrating from the site in groundwater to areas down-gradient. Groundwater monitoring bores surround the entire site; both up-gradient (south) and down-gradient (west, north and east). There are also some bores centrally located within the site. Most bore locations include a shallow bore, screened between 1.5 and 3 m below ground level (mBGL), and a deeper bore, screened between 9 and 12 mBGL. Some sites also include a deep bore up to 30 m deep. This network comprises bores installed during two separate drilling campaigns as outlined below.

Bores installed in 2015 to inform the URS (2015) hydrogeological investigation:

Includes a total of 32 bores at 15 locations across the site, with up to 3 bores at each location at different depths. Generally, each of the 15 locations includes a shallow bore screened between 1.5 and 3 mBGL, and a deeper bore screened between 9 and 12 mBGL. Three of the locations have a third bore screened at a deeper level; the deepest being 30 mBGL. The ID's for these bores are prefixed with a 'GW' and suffixed with a -3, -12 or -30 to indicate the bore depth.

All these bores are included in the URS (2016a) Water Monitoring Plan.

Bores installed in 2012:

Includes 8 bores with the prefix 'WW' at varying depths; all less than 10 m, except for WW3 and WW6, which are 20.3 m and 20.4 m deep respectively. All bores are at different locations, except for WW6 and WW7, which are at the same location but have different depths (20.4 m and 5.8 m respectively).

All these bores are included in the URS (2016a) Water Monitoring Plan, except for WW6, which is additional to the plan.

4.3.2 Surface water sites

Surface water monitoring aims to detect any land fill leachate, or other contaminants, in surface water runoff that could potentially flow offsite to environments downstream. Surface water monitoring sites comprise the following:

- 'Wheelwash' sump that collects wash-down water from the bunded area used to wash commercial waste disposal vehicles
- 'GW Sump' that collects surface water drainage from the green waste processing and storage area
- 'SW12' catchment dam that receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3 and 4 landfill cells
- 'STG1&2' surface water drain that receives surface water runoff from central areas of the waste management facility
- 'SW2' that was included in the URS (2016a) Water Monitoring Program reportedly as a site potentially receiving seepage during the wet season from the Stage 3/4 landfill cells. This site however, has only had enough surface water to be sampled once since monitoring began (i.e. in November 2016). As such, this site is excluded from any further discussions in the sections below.

Further surface water monitoring site details are provided in Table 4-2.

4.3.3 Leachate sites

Leachate sampling aims to allow the characterisation of contaminant concentrations in leachate for comparison with groundwater and surface water results. Leachate sampling sites comprise the following:

- 'DW2' deleaching well that collects leachate from the south-west corner of the Stage 3/4 landfill
- 'DW3' deleaching well that collects leachate from the north-west corner of the Stage 3/4 landfill
- 'TC Sump' that collects leachate from the eastern side of the Stage 3/4 landfill
- 'DW5' deleaching well that collects leachate from the western side of the Stage 5 landfill
- 'DW6' deleaching well that collects leachate from the south-west corner of the Stage 5 landfill
- 'LP01' northern leachate storage pond
- 'LP02' southern leachate storage pond

- ‘LMP02’ sump at the end of a trench that runs along the western side of the Stage 1 and Stage 2, landfills and collects leachate from these landfills.

Leachate monitoring sites DW2 and LMP02 are the only sites listed in the original URS (2016a) Water Monitoring Plan. TC Sump, LP01 and LP02 were added to the monitoring program when it started in July 2016. DW5 was added to the program in June 2019, and DW6 in November 2019, following establishment of the Stage 5 landfill.

The leachate monitoring site DW1, listed in the URS (2016a) Water Monitoring Plan was never operational and never sampled.

Further leachate monitoring site details are provided in Table 4-2.

Table 4-1. Groundwater monitoring bore details.

[1] *"Time of year sampling usually possible", is based on average, to above average, rainfall year i.e. 2016/17 and 2017/18 wet seasons. The 2018/19 and 2019/20 wet seasons were below average.*

[2] *Top of casing (TOC) PVC bore casing; standing water levels (SWLs) measured during monitoring rounds are measured from this point.*

[3] *Top of outer steel casing around PVC bore casing to protect the top of the bore.*

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
GW1-3	709564	8631004	On floodplain, 190 m north of leachate storage area	8.71	8.63	8.02	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2019/20 wet season.
GW1-12	709566	8631004		8.71	8.59	8.00	9-12	Siltstone	All wet season (December–May)	
GW2-3	709629	8630835	On north-east corner of leachate storage area	8.06	7.94	7.33	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
GW2-12	709631	8630835		8.08	7.94	7.28	9-12	Siltstone	All wet season and early dry season (November–July)	
GW3-3	709652	8630746	East of leachate storage area	9.94	9.80	9.12	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
GW3-12	709654	8630746		9.87	9.82	9.10	9-12	Siltstone	All wet season and early dry season (November–July)	
GW4-3	709775	8630634	On floodplain, north of Stage 2 landfill	5.65	5.49	4.88	1.5-3	Siltstone	All wet season (December-April)	GW4 bores were inaccessible due to wet ground conditions and could not be sampled January 2019, January 2020 and March 2020.
GW4-12	709776	8630633		5.61	5.44	5.36	9-12	Siltstone	All wet season and early dry season (November–July)	
GW4-30	709777	8630631		5.50	5.20	5.33	15-21	Gravelly sand, Sandstone	Throughout the year Groundwater is usually at top of casing or overflowing during wet season (December – May)	
GW5-3	709880	8630224	East of Stage 2 landfill	5.51	5.41	4.70	1.5-3	Siltstone	All wet season (December-April)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019, February 2020 and March 2020.
GW5-12	709880	8630226		5.48	5.33	4.70	9-12	Siltstone, Gravelly Clay	Throughout the year Groundwater is usually at top of casing or overflowing during wet season (December – May)	

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
GW6-3	709464	8630022	Centre of SBWMF, south of Stage 3, south-west of Stage 2 and north-west of Stage 1	14.39	14.24	13.60	1.5-3	Gravelly Sandy Silt, Siltstone	All wet season (December-April)	Bore was dry most of 2018/19 wet season and could only be sampled March 2019. Decommissioned in early Sept 2019, and not sampled during 2019/20 wet season.
GW6-12	709464	8630021		14.37	14.18	13.66	9-12	Siltstone	Throughout the year	Can be dry at end of long dry season. Was dry August 2019. Decommissioned in early Sept 2019, so not sampled during 2019/20 wet season.
GW6-30	709464	8630018		14.24	14.12	13.60	17.7-23.7	Siltstone, Sandstone	Throughout the year	Can be dry at end of long dry season. Was dry December 2017 and December 2018. Decommissioned in early Sept 2019, and not sampled during 2019/20 wet season.
GW7-3	709900	8629992	South-east of Stage 2 and north-east of Stage 1	5.18	5.03	4.33	1.5-3	Siltstone	All wet season (November - April)	GW7 bores were inaccessible due to wet ground conditions and could not be sampled January 2020
GW7-12	709900	8629994		5.16	5.08	4.33	9-12	Siltstone, Sandy Silt	Throughout the year Groundwater is usually at top of casing or overflowing during wet season (December – May)	
GW8-3	709896	8629708	East of Stage 1	5.42	5.28	4.65	1.5-3	Claystone	All wet season and early dry season (November–July) Groundwater can be at top of casing or overflowing during mid-wet season (January - March)	
GW8-12	709896	8629708		5.37	5.22	4.62	9.1-12.1	Claystone, Sandstone	Throughout the year	
GW9-12	709660	8629469	On southern boundary of SBWMF – up-gradient of all SBWMF operations and infrastructure	16.18	15.93	15.44	9-12	Siltstone	All wet season (November - April)	Bore was dry most of 2019/20 wet season and could only be sampled March 2020.
GW10-3	709147	8629507	South of SBWMF – up-gradient of all SBWMF operations and infrastructure	18.12	18.06	17.32	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2019/20 wet season.
GW10-12	709149	8629507		18.13	17.98	17.37	9.1-12.1	Siltstone	All wet season (November - April)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and March 2020.

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
GW11-3	709040	8629671	South-west corner of SBWMF	13.50	13.38	12.72	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2019/20 wet season.
GW11-12	709042	8629671		13.52	13.38	12.84	9-12	Siltstone, Sandstone	All wet season and early dry season (November–July)	
GW12-3	709024	8629881	West of green waste area	12.20	12.07	11.44	1.5-3	Siltstone	All wet season (December - April)	Bore was dry for entire 2019/20 wet season.
GW12-12	709024	8629883		12.22	12.04	11.50	9-12	Siltstone	All wet season and early dry season (November–June)	
GW12-30	709024	8629885		12.21	12.05	11.55	24-30	Sandstone	Throughout the year	Bore was dry in December 2018.
GW13-3	709017	8630175	On south-west corner of Stage 3/4 and north-west corner of Stage 5 landfills	12.93	12.88	12.32	3-4.5	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
GW13-12	709016	8630174		12.91	12.86	12.25	10-13.5	Siltstone	All wet season and early dry season (November–June)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and January 2020.
GW14-3	709013	8630423	West of Stage 4 landfill	6.78	6.73	6.09	1.5-3	Siltstone	All wet season (December - April)	Bore was dry most of 2018/19 wet season and could only be sampled March 2019. Bore was dry for entire 2019/20 wet season.
GW14-12	709013	8630424		6.77	6.64	6.08	9-12	Siltstone	Throughout the year	Bore was dry between September 2018 and January 2019. Also dry between June 2019 and January 2020.
GW15-3	709230	8630599	North of Stage 3/4 landfill	11.27	11.06	10.44	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and March 2020.
GW15-12	709233	8630599		11.20	11.04	10.44	9-12	Siltstone	All wet season and early dry season (November–June)	
WW1	709471	8630151	Between Stage 3 and Stage 2 landfills		16.60	15.90	0-6.3	-	Usually always dry	Bore could be sampled after very wet periods in January 2017, January 2018 and March 2018.
WW3	709471	8630151	South-east corner of Stage 3 and west of Stage 2		16.38	15.68	0-20.3	-	Only mid wet season (January-March)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and March 2020.
WW5	708980	8630234	West of Stage 3/4 landfill		8.34	7.64	0-6.0	-	All wet season (December - April)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
WW6	709047	8630478	North-west corner of Stage 3/4 landfill		7.46	6.76	0-20.4	-	Throughout the year	
WW7	709045	8630483			7.45	6.75	0-5.8	-	All wet season (December - April)	Bore was dry most of 2018/19 wet season and could only be sampled March 2019. Bore was dry for entire 2019/20 wet season.

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
WW9	709016	8630598	North-west corner of SBWMF		7.09	6.39	1-9.8	Siltstone	All wet season and early dry season (November–July)	Bore could not be accessed for sampling February 2017. Was dry early wet season in 2018/19 and 2019/20, and could only be sampled January and March 2019 and January and March 2020.
WW10	709235	8630598	On northern boundary of SBWMF		10.92	10.21	1-9.7	Siltstone	All wet season and early dry season (November–June)	Bore was dry most of 2018/19 wet season and could only be sampled January and March 2019. Bore was dry for entire 2019/20 wet season.
WW13	709457	8630598	On northern boundary of SBWMF	+0.8	+0.7	Not available	1-10	Siltstone	All wet season (January -April)	Bore was dry for entire 2018/19 wet season and could only be sampled once during 2019/20 wet season (March 2020). .

Table 4-2. Surface water and leachate sampling site details.

**"Time of year sampling usually possible" is based on average, to above average, rainfall year i.e. 2016/17 and 2017/18 wet seasons. The 2018/19 and 2019/20 wet seasons were below average.*

^ During the period September 2017 to June 2019, EcOz was advised not to sample the leachate sites DW2, DW3, TC Sump, LP01 and LP02, and were being sampled by a different contractor as part of an investigation into leachate management options. EcOz has not been able to obtain any data for this period.

Site ID	Easting	Northing	Location	Context	Time of year sampling usually possible*	Exceptions to usual sampling
Surface Water Sites						
Wheel Wash	709479	8629775	Sump within vehicle wash-down bay	Receives wash-down water from large commercial waste transport vehicles	Throughout the year	Sump was dry on one occasion; April 2017.
STG1&2	709448	8629979	Surface drain between Stage 1 and Stage 2	Receives surface water runoff from central SBWMF areas	Only flows during or immediately after rain. Usually can only be sampled during mid-wet season (January and February)	Site was dry during all sampling occasions during 2018/19 and 2019/20 wet seasons.
GW Sump	709102	8629880	Sump within green waste processing and storage area	Receives surface water runoff from green waste processing and storage area. Possibly also surface runoff from the Stage 3 and 5 landfills.	All wet season (October - April)	
SW2	708973	8630296	West of Stage 3/4 landfill	Receives seepage from Stage 3/4 landfill	Usually always dry	Site has only has only had water flows and been able to be sampled once since July 2016. This was in November 2016.
SW12	709035	8630495	Catchment dam at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells	Catchment dam contains water and can be sampled for most of the year (October to June) and only dries out mid to late dry season	Dam had been pumped out and was dry in March 2020.
Leachate Sites						
DW2	709029	8630459	Deleaching well on southwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells	Throughout the year	Site was not sampled Sept 2017 to June 2019^
DW3	709038	8630216	Deleaching well on northwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells	Throughout the year	Site was dry and could not be sampled May 2017. Site was not sampled Sept 2017 to June 2019^.
DW5	709023	8630122	Deleaching well on west side of Stage 5 landfill	Represents leachate from Stage 5 landfill cell	Site has only been monitored since June 2019, and typical sampling regime is not yet known. Site has had water available for sampling on all monitoring occasions since June 2019, except for Sept and Oct 2019.	
DW6	709041	8630039	Deleaching well on southwest corner of Stage 5 landfill	Represents leachate from Stage 5 landfill cell	Site has only been monitored since November 2019, and typical sampling regime is not yet known. Site has had water available for sampling on all monitoring occasions since November 2019, except for March 2020.	

Site ID	Easting	Northing	Location	Context	Time of year sampling usually possible*	Exceptions to usual sampling
TC Sump	709465	8630233	Sump on southeast corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells	Throughout the year	Site was not sampled Sept 2017 to June 2019^.
LMP02	709938	8629759	East of Stage 1	Sump that receives leachate from Stage 1 and 2 landfills via an interception trench that runs north-south along the eastern edge of the Stage 1 and 2 landfills.	Throughout the year	
LP01	709534	8630726	Northern leachate storage pond	Represents leachate in northern storage pond	Throughout the year	Could not be sampled March 2020. Site was not sampled Sept 2017 to June 2019^.
LP02	709531	8630713	Southern leachate storage pond	Represents leachate in southern storage pond	Throughout the year	Could not be sampled January 2020. Site was not sampled Sept 2017 to June 2019^.

4.4 Sampling frequency

The URS (2016a) Water Monitoring Plan requires monthly sampling of all monitoring sites. Many monitoring sites however, are dry for various periods of the year and cannot always be sampled. The surface water site STG1&2 only has water during, and immediately after, heavy rainfall, and the catchment dam SW12 and GW Sump can dry up during the dry season. Also, during the dry season, the lowering of groundwater levels means that many groundwater bores become dry.

The typical availability of each monitoring site for sampling throughout the year is outlined in Table 4-1 and Table 4-2. These tables also outline for the monitoring period June 2016 to March 2020, where exceptions to the typical availability of sites for sampling occurred, such as when sites were inaccessible due to wet ground conditions, or drier for longer due to below average rainfall.

Sampling is carried out during the first week of each month, and this is taken to represent water quality of the previous month e.g. sampling during the first week of July is taken to represent the month of 'June'.

The required monthly schedule of sampling was adhered to consistently for the two years between July 2016 and June 2018. Sampling was then undertaken less frequently between July 2018 and August 2019 due to the program being in a state of review. During this period, sampling was undertaken for September 2018, December 2018, January 2019, March 2019 and June 2019. From August 2019 onwards, sampling returned to monthly.

During the period September 2017 to June 2019, EcOz was advised not to sample the leachate sites DW2, DW3, TC Sump, LP01 and LP02, as these were being sampled by a different contractor as part of an investigation into leachate management options. EcOz has not been able to obtain any data for this period.

4.5 Parameters measured

The physical parameters pH, temperature, electrical conductivity (EC) and dissolved oxygen (DO) are measured at all groundwater, surface water and leachate sampling sites during all monthly monitoring rounds. These are measured in the field using hand-held meters.

The standing water level (SWL) is always measured in each groundwater monitoring bore prior to the commencement of pumping and sampling. The SWL is measured starting from the top of the bore casing (TOC) i.e. the top of the PVC bore casing, not the outer steel protective casing.

A differing suite of laboratory parameters is analysed on a monthly, quarterly and annual basis; as outlined in Table 4-3. Table 4-4 provides which parameter suite was analysed during each monitoring round from July 2016 to March 2020.

A ratio of L/N is used to determine if additional parameters are analysed for groundwater bores, when they record a L/N ration greater than 10. The L/N ratio indicates the degree of impact on groundwater from leachate; as explained in Section 4.6 below. Additional parameters are added to the next monitoring round where a bore records an L/N greater than 10.

Per and poly-fluoroalkyl substances (PFAS), including 28 different species, were added to the quarterly parameter suite for groundwater and leachate sites in June 2019. As such, PFAS have only to date, been measured on three occasions; June 2019, October 2019 and January 2020.

Table 4-3. Water quality monitoring parameters and schedule.
For parameter acronyms and abbreviations refer to the list at the front of this document.
**PFAS (including 28 species) were added to quarterly suite from June 2019 onwards.*

Frequency	Sample type	Standard suite	If L/N >10
Monthly	Groundwater	**Field parameters:** SWL, pH, EC, DO, temperature **Lab parameters:** major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), NH_4, TDS, COD, TOC	NA
	Surface water	**Field parameters:** pH, EC, DO, temperature **Lab parameters:** alkalinity, SO_4, NH_4, Cl, COD, TOC	NA
	Leachate	**Field parameters:** pH, EC, DO, temperature **Lab parameters:** TOC, COD	NA
Quarterly	Groundwater	**Field parameters:** SWL, pH, EC, DO, temperature **Lab parameters:** major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), nutrients (NH_4, TON, nitrate as N, reactive phosphorus as P), metals (dissolved) (Cd, CrIII, CrVI, Cu, FeII, FeIII, Pb, Mn, Ni, Zn), TRHs, PAHs, COD, TOC, PFAS*	BTEXN, total phenolics
	Leachate	**Field parameters:** pH, EC, DO, temperature **Lab parameters:** major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), nutrients (NH_4, TON, nitrate as N, reactive phosphorus as P), metals (dissolved) (Cd, CrIII, CrVI, Cu, FeII, FeIII, Pb, Mn, Ni, Zn), COD, TOC, TRHs, PAHs, BTEXN, total phenolics, PFAS*	NA
Annual (wet season)	Groundwater	**Field parameters:** SWL, pH, EC, DO, temperature **Lab parameters:** major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), nutrients (NH_4, TON, Nitrate as N, reactive phosphorus as P), metals (Dissolved) (Cd, CrIII, CrVI, Cu, FeII, FeIII, Pb, Mn, Ni, Zn), COD, TOC	TRHs, PAHs, BTEXN, total phenolics, other leachate indicators, PCB, TNT, RDX
	Surface water	**Field parameters:** pH, EC, DO, temperature **Lab parameters:** major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), nutrients (NH_4, TON, Nitrate as N, reactive phosphorus as P), metals (Dissolved) (Cd, CrIII, CrVI, Cu, FeII, FeIII, Pb, Mn, Ni, Zn), COD, TOC	TRHs, PAHs, BTEXN, total phenolics, other leachate indicators, PCB, TNT, RDX
	Leachate	**Field parameters:** pH, EC, DO, temperature **Lab parameters:** major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), nutrients (NH_4, TON, nitrate as N, reactive phosphorus as P), metals (dissolved) (Cd, CrIII, CrVI, Cu, FeII, FeIII, Pb, Mn, Ni, Zn), TRHs, PAHs, BTEXN, total phenolics, other leachate indicators, PCB, TNT, RDX, COD, TOC	NA

Table 4-4. Parameter suite analysed during each monitoring round June 2016 to March 2020.

Date	Suite analysed	Date	Suite analysed
July 2016	Monthly	January 2018	Annual
August 2016	Monthly	February 2018	Monthly
September 2016	Quarterly	March 2018	Quarterly
October 2016	Monthly	April 2018	Monthly
November 2016	Monthly	May 2018	Monthly
December 2016	Quarterly	June 2018	Quarterly
January 2017	Annual	September 2018	Quarterly
February 2017	Monthly	December 2018	Quarterly
March 2017	Quarterly	January 2019	Annual
April 2017	Monthly	March 2019	Quarterly
May 2017	Monthly	June 2019	Quarterly
June 2017	Quarterly	August 2019	Monthly
July 2017	Monthly	September 2019	Monthly
August 2017	Monthly	October 2019	Quarterly
September 2017	Quarterly	November 2019	Monthly
October 2017	Monthly	December 2019	Monthly
November 2017	Monthly	January 2020	Quarterly
December 2017	Quarterly	February 2020	Annual
		March 2020	Monthly

4.6 Assessment criteria

The assessment criteria applied to water quality monitoring results at the SBWMF aims to minimise the risk of impacts to the environmental values/beneficial uses listed in Section 3.5 above from leachate, or other potential pollutants, or operational activities at the facility.

Aquatic organisms in the estuarine and marine waters of Shoal Bay are the most sensitive potential environmental receptor downstream of the SBWMF. In regards to this, EPL188 Condition 61 specifies the assessment criteria to be applied to monitoring results; as the *Australian and New Zealand Guidelines for Marine and Freshwater Quality* (ANZECC 2000) trigger values for 90% species protection in marine waters. Usually, the more conservative 95% species protection level is required in most other areas in the NT. However, given the degree of urbanisation and development in the catchment of the SBWMF, the level of protection is set at the lower 90% species protection.

ANZECC (2000) trigger values are only available for toxicant parameters (i.e. dissolved metals, ammonia, PAHs etc.). Assessment criteria for physical parameters and nutrients e.g. pH, total nitrogen (TN), nitrate+nitrite (NOx), total phosphorus (TP) and filterable reactive phosphorus (FRP), are therefore taken from the *Water Quality Objectives for the Darwin Harbour Region – Background Document* (NRETAS 2010) for the 'Upper Estuary'. These are the only available local guidelines.

In regards to per and poly-fluoroalkyl substances (PFAS), assessment criteria are taken from the *PFAS National Environmental Management Plan* (NEMP). The human-health guidance values for 'recreational water' are used, noting these values are more conservative than the PFAS NEMP aquatic ecosystems 90% species protection values.

The water monitoring plan utilises a leachate impact indicator to detect the degree of leachate in groundwater. The indicator involves comparing the concentrations of ions typically associated with leachate (K^+, NH_4^+, NO_3^-) to ions typically associated with natural groundwater (Ca^{2+}, Na^+, Mg^{2+}). The leachate (L) to natural groundwater (N) ratio is determined as follows:

$$L/N = (K^+ + NH_4^+ + NO_3^-) / (Ca^{2+} + Na^+ + Mg^{2+}) \times 100$$

The L/N ratio is generally less than 10 for natural groundwater and greater than 10 for leachate impacted groundwater. An L/N ratio greater than 10 is a trigger for further investigation.

5 RAINFALL AND SITE CONDITIONS

The availability of water for sampling at a number of groundwater and surface water sites is dependent on rainfall (see Table 4-1 and Table 4-2 above). Groundwater recharge is via direct infiltration of rainfall and runoff, and groundwater levels in the shallow aquifer are highly responsive to rainfall totals. Surface water only flows in stormwater drains across the site during and immediately after rainfall. Whereas surface water storages such as SW12 and GW Sump contain water for longer periods. The wheel wash site receives vehicle wash-down water sourced from the Darwin reticulated water supply and is not dependent on rainfall.

The amount of rainfall may also influence the extent of contaminant migration; for example, during an above average wet season, higher groundwater levels, and extensive surface water flows may potentially mean contaminants travel further downstream of the site; although concentrations may also be more diluted.

Figure 5-1 shows monthly rainfalls from July 2016 to March 2020, for the nearest BoM station with consistent, reliable rainfall data (Darwin Airport Station No. 014015). The average annual rainfall for this station is 1,723 mm. The 2016/17 wet season rainfall, between the months of September and May, was above average (2,549 mm). The 2017/18 wet season rainfall total for the same period was also above average (2,039 mm). The 2018/19 wet season was below average (1,242 mm) and the 2019/20 wet season also below average (1,180 mm). February 2017 and January 2018 experienced extremely high rainfall, with monthly totals of 625 mm and 893 mm respectively.

During and after the below average 2018/19 and 2019/20 wet seasons, groundwater levels were lower and bores became dry earlier compared to the previous two wet seasons (see Table 4-1 above). Similarly, surface water sites were able to be sampled less frequently and dried out earlier compared to the previous two wet seasons.

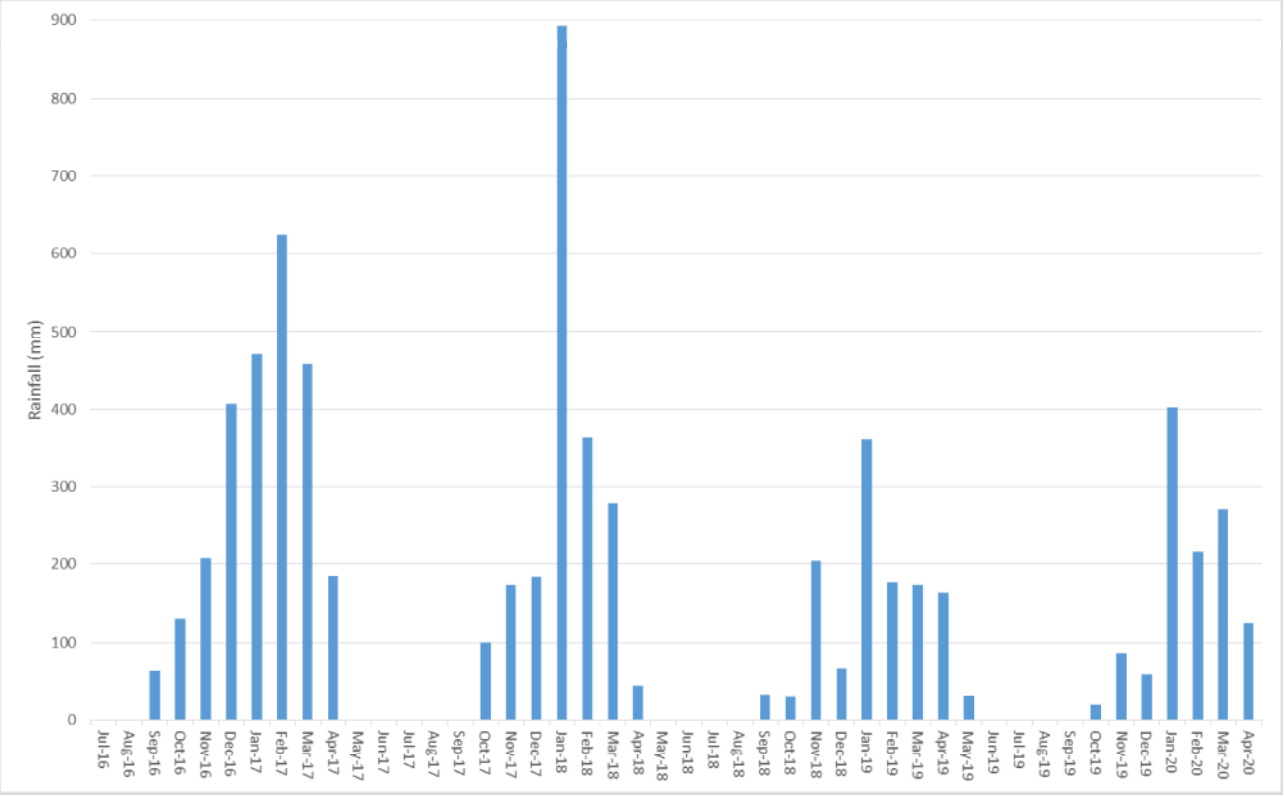


Figure 5-1. Monthly rainfall totals between July 2016 and April 2020.
Taken from the Darwin Airport BoM Station (No. 014015).

6 GROUNDWATER LEVELS AND FLOWS

The analysis of groundwater levels and flows has been divided into the following two sections;

- Investigation of groundwater levels across the site and connectivity between shallow and deeper aquifers
- Analysis of groundwater flow directions across the site and potential implications for leachate migration.

As discussed in Section 3.4 detailed analysis of the lithology that lay beneath SBWMF, is discussed in detail in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015). Geology of the site is generally comprised top soils (silts and clays), generally underlain by weathered (lateritised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9 to 20 m below the surface across most of the site. Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. The higher yielding weathered and fractured carbonate rock aquifers that occur in the wider region commonly yield greater than 5 L/sec.

6.1 Seasonal groundwater levels and connectivity

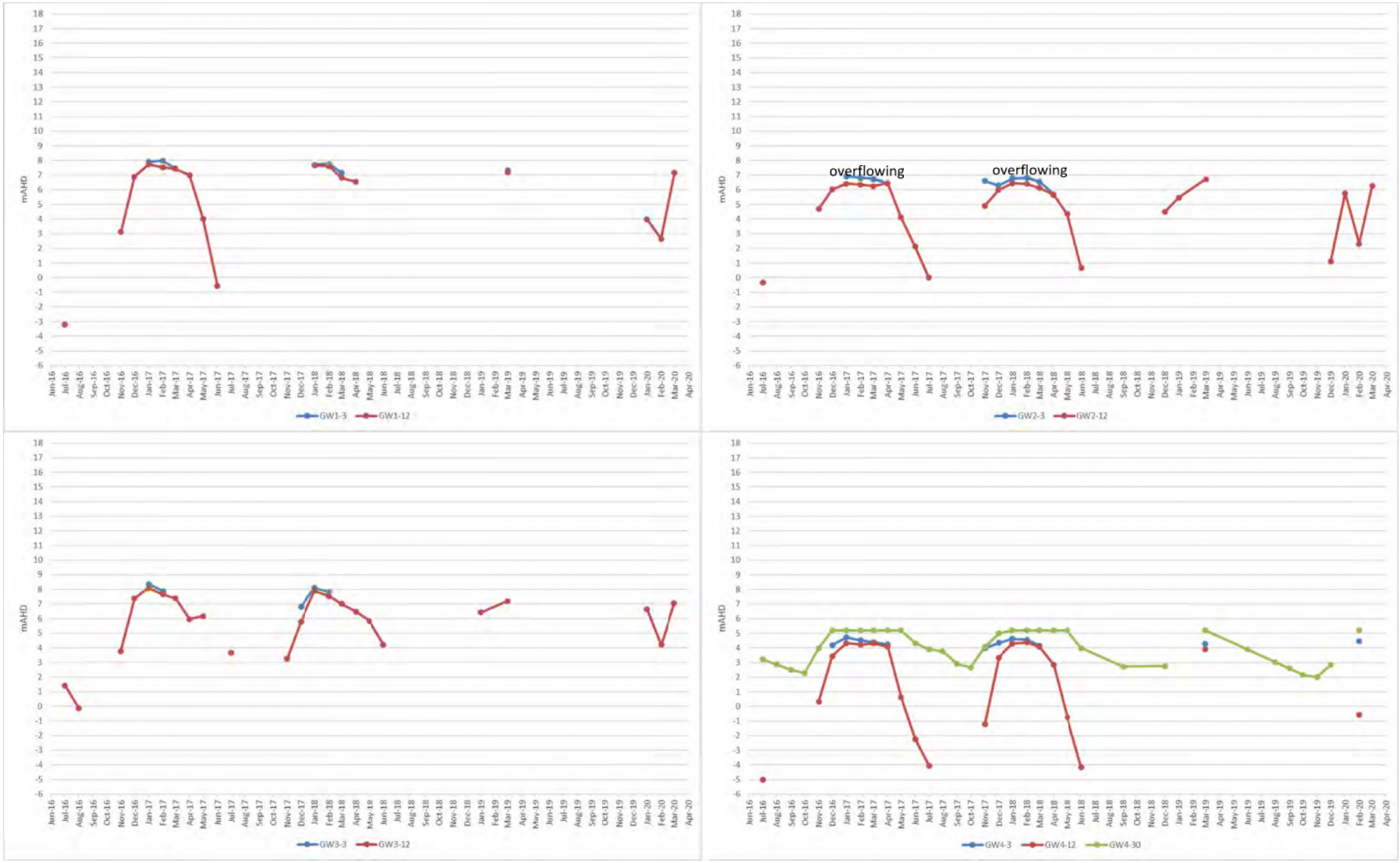
As part of the monitoring program, the standing water levels (SWLs) were measured in the bores below the top of casing (TOC). For the purposes of this report, these values have been converted to mAHD to allow for a comparison of groundwater levels across the site. Figure 6-1 shows the graphed groundwater levels in mAHD at each set of bores from July 2016 and March 2020. Analysis of these graphs identifies three key patterns, which are summarised in Table 6-1, below.

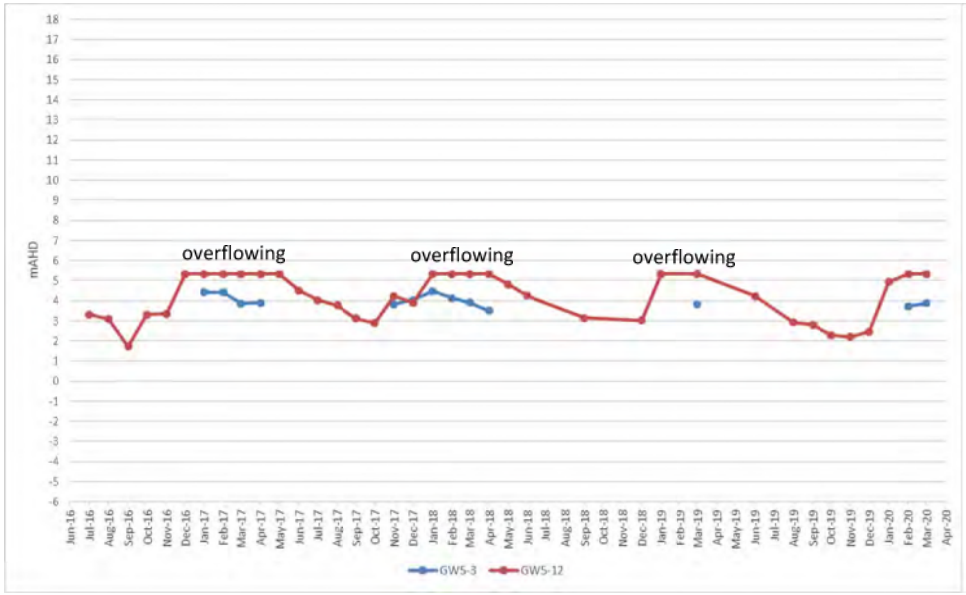
Table 6-1. Seasonal groundwater level trends

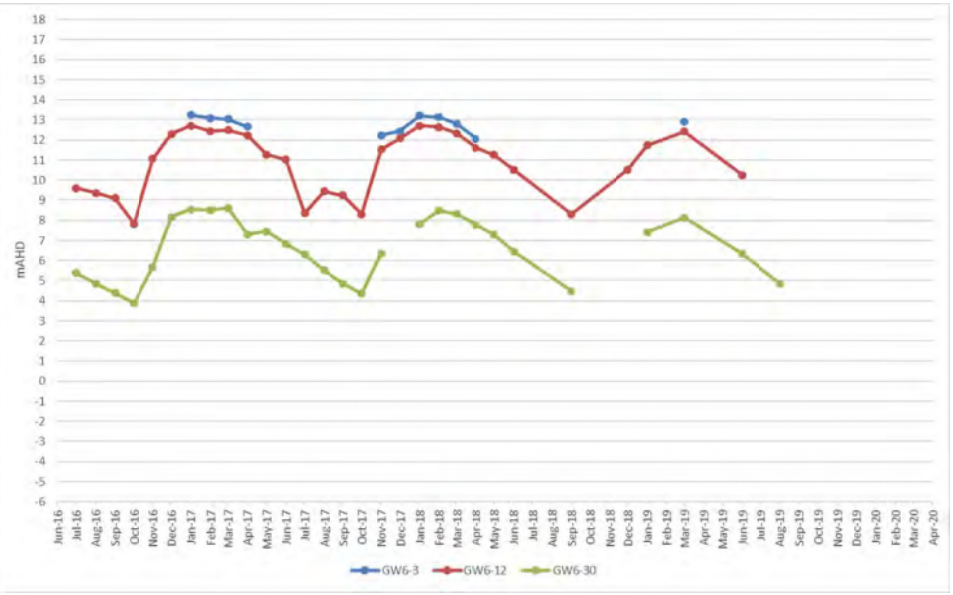
Bores	Trend	Explanation
GW1-3, GW1-12, GW2-3, GW2-12, GW3-3, GW3-12 GW4-3, GW5-3, GW6-3, GW7-3, GW8-3, GW9-12, GW10-3, GW10-12, GW11-3, GW11-12, GW12-3, GW13-3, GW13-12, GW14-3, GW14-12, GW15-3, GW15-12, WW1, WW3, WW5, WW6, WW7, WW9 and WW10	Constantly dry in the dry season, with recharge occurring in the wet season.	These bores are located in the shallow surface water aquifer, whereby recharge occurs via direct infiltration from rainfall and runoff. Water levels are higher during the wet season, with a sharp drop once dry season begins, impacting both the 3 m and 12 m bores.
GW5-12, GW7-12 and GW8-12	12 m bores that are rarely dry and follow distinctive seasonal trend.	All bores are located on the eastern boundary of SBWMF and are likely to be impacted by the fractured carbonate rock aquifers, located south-east of the site. These 12 m bores are rarely dry and during the wet season, water levels reach 5 mAHD and in the dry season sit between 1-2 mAHD. GW5-12 and GW7-12 consistently overflow in wet season, likely due to their topographic positioning. The 3 m bores nested at these sites are listed above and are dry during the dry season and therefore do not follow the same seasonal trend.

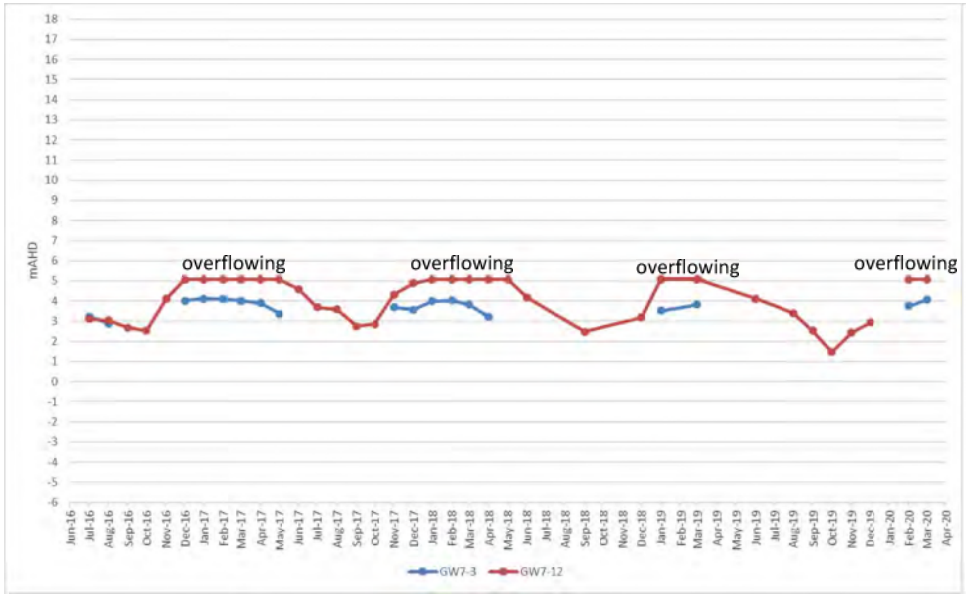
Bores	Trend	Explanation
GW4-12, GW4-30, GW6-12, GW6-30 (now decommissioned) and GW12-12, GW12-30	Distinctive seasonal patterns are observed for these 12 m and 30 m bores. Bore are never dry throughout the year.	These bores are scattered across the site. The three 30 m bores are located within a sandstone aquifer. Bore logs for GW4-30 show a clear confining clay layer, which applies pressure to the groundwater under this layer, creating higher hydraulic head within the bore itself, causing it to consistently overflow during heavy rainfall events. GW6-30 and GW12-30 do not have the same confining layer and therefore do not overflow. GW6-30 is observed to be located in a different aquifer than GW6-3 and GW6-12. The difference in water levels during the wet season are significantly lower (approximately 4.5 m). The 3 m bores nested at these sites are listed above and are dry during the dry season and therefore do not follow the same seasonal trend.

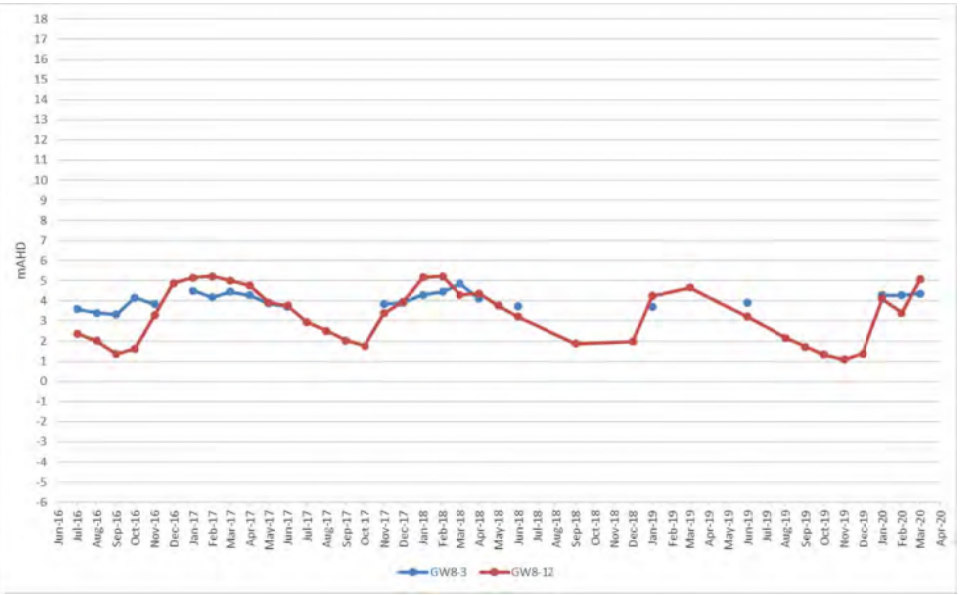
Figure 6-1. Graphs of groundwater levels in mAHD measured in all bores July 2016 to March 2020



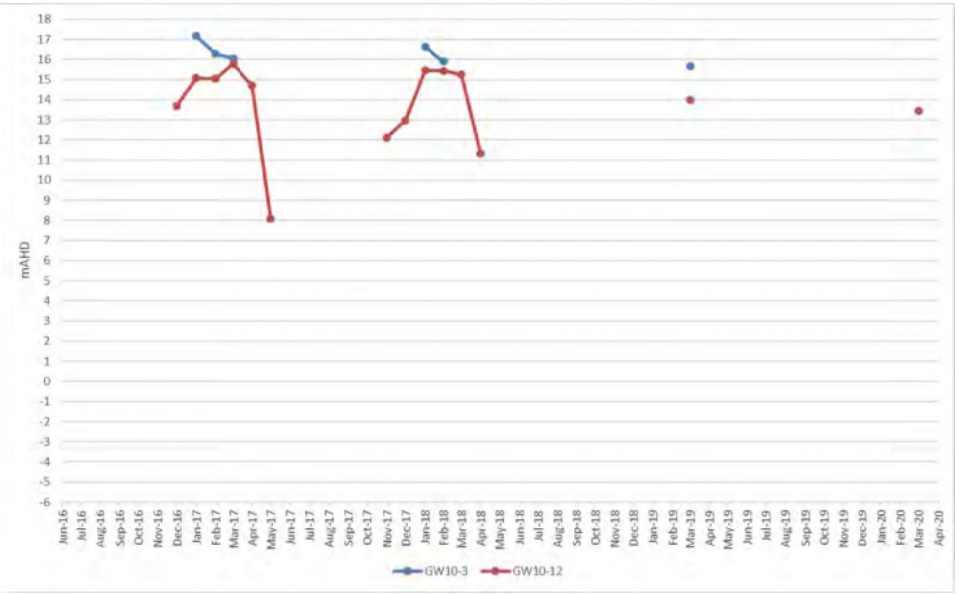

mAHD
overflowing
overflowing
overflowing
GW5-3
GW5-12


mAHD
GW6-3
GW6-12
GW6-30

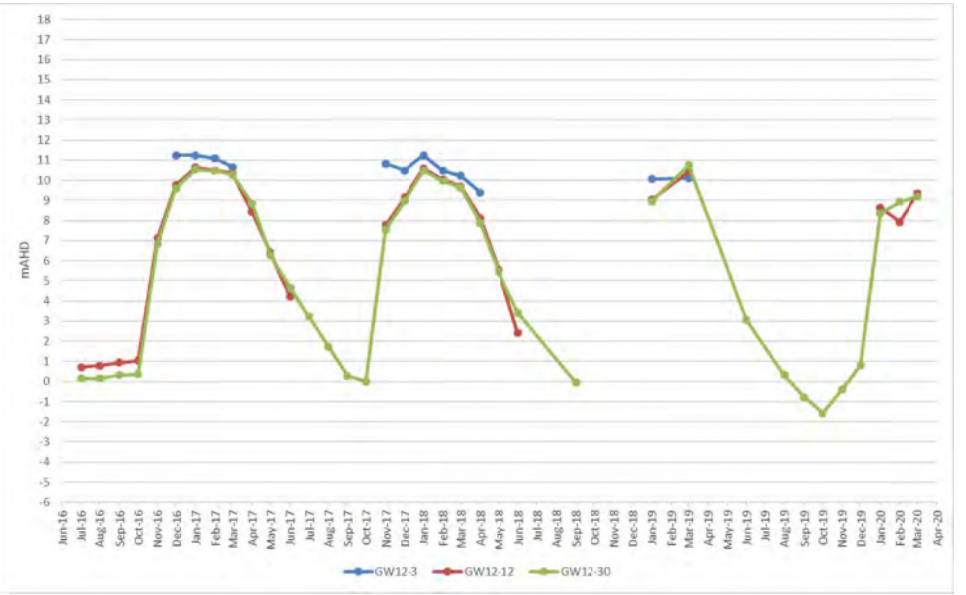

mAHD
overflowing
overflowing
overflowing
overflowing
GW7-3
GW7-12


mAHD
GW8-3
GW8-12

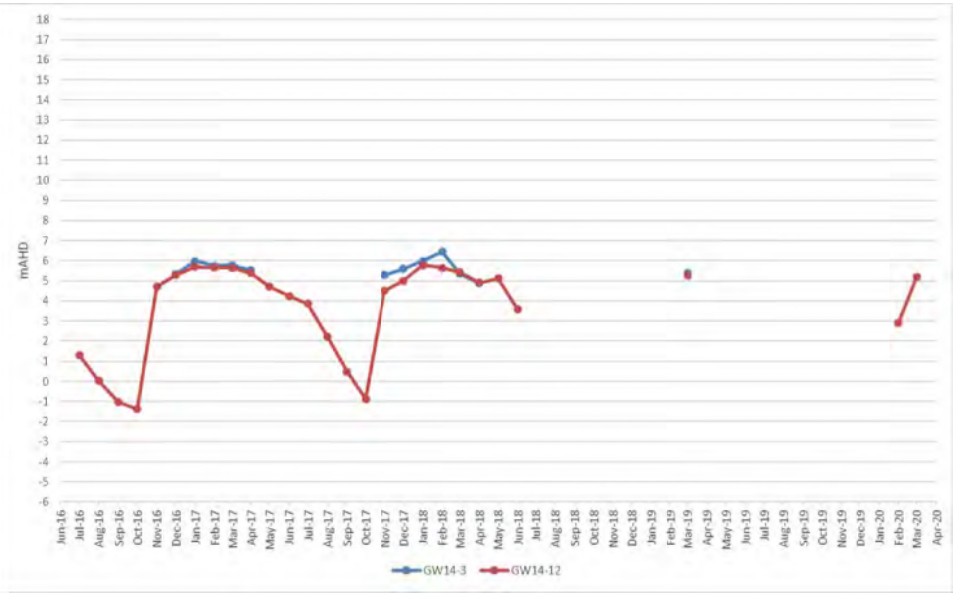

mAHD
GW9-12

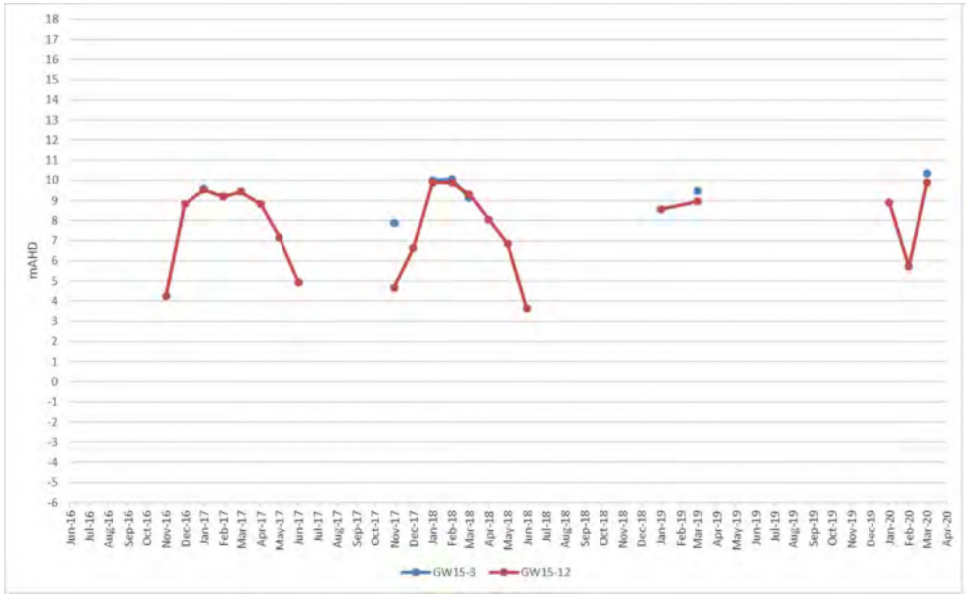

mAHD
GW10-3
GW10-12

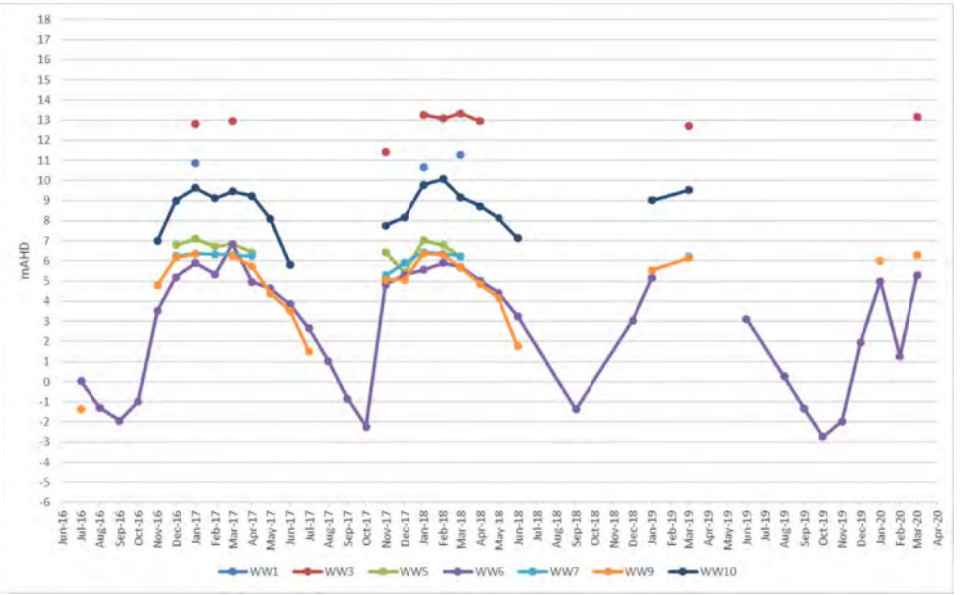

mAHD
GW11-3
GW11-12


mAHD
GW12-3
GW12-12
GW12-30


mAHD
GW13-3
GW13-12


mAHD
GW14-3
GW14-12


mAHD
GW15-3
GW15-12


mAHD
WW1
WW3
WW5
WW6
WW7
WW9
WW10

6.2 Groundwater flow direction

Groundwater level and flow maps were developed to display the hydraulic behaviour of groundwater using the 12 m deep bores, during the mid-wet season (January 2017) and mid-dry season (June 2017). SBWMF topographically, sits on a low-lying peninsula with tributaries from the Leanyer Swamp located on the western and eastern boundaries of the site.

General patterns observed in Figure 6-2 and Figure 6-3, illustrate that the groundwater contours mimic the topography of the site, with higher groundwater levels through the centre of the site (i.e. GW6, GW10, GW15, WW3 and WW10) and lower levels on the eastern and western boundaries (i.e. GW4, GW5, GW7, GW8, GW14). Groundwater is flowing in a western, eastern and north-eastern direction, towards the Leanyer Swamp tributaries.

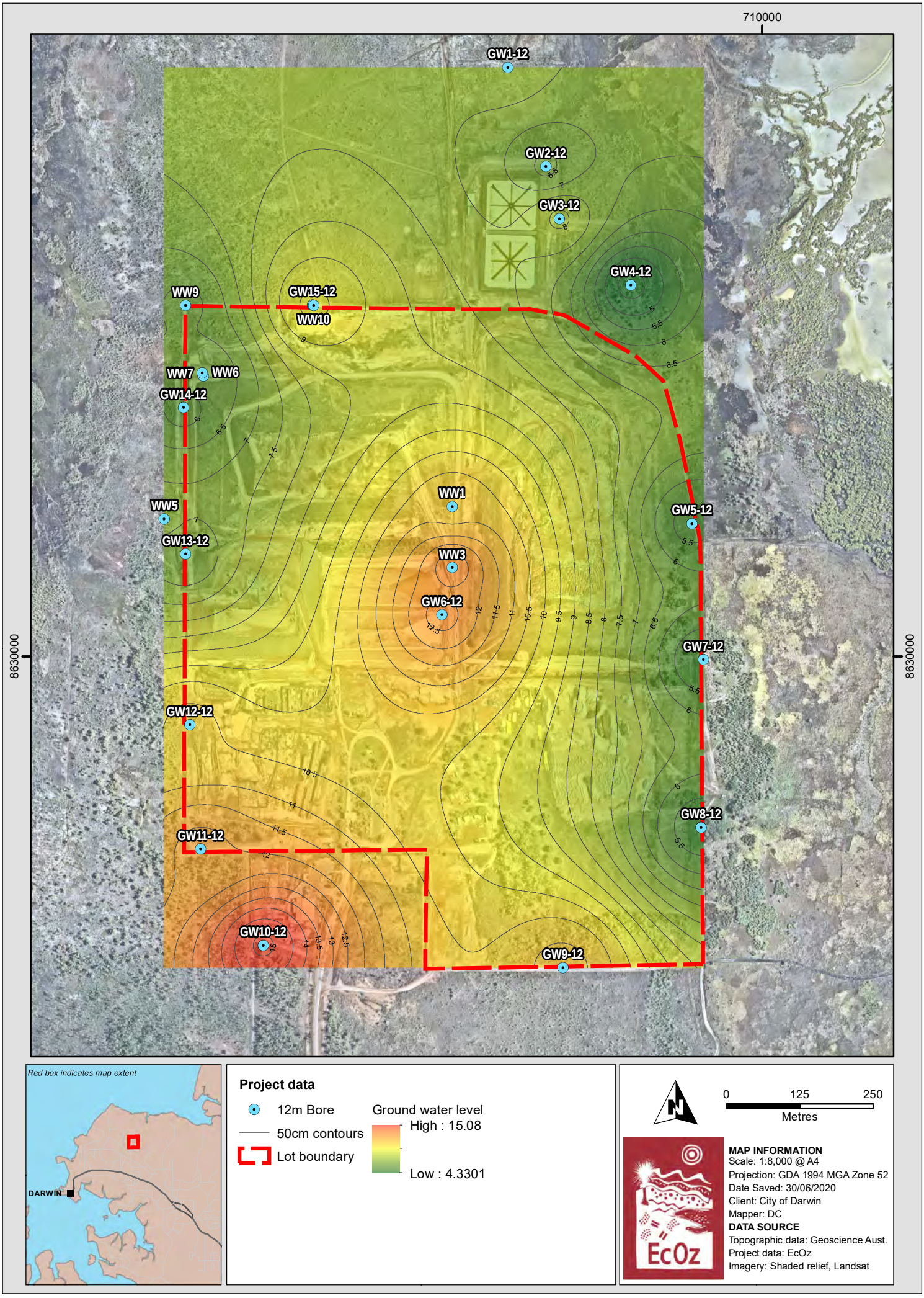
Figure 6-2 illustrates the groundwater contours in January 2017 (mid-wet season). During this sampling period, standing water levels (SWLs) were measured at 22 of the 12 m bores, providing an adequate overview of the hydraulic behaviours of the groundwater across the site, including its boundaries. Groundwater levels were highest at GW10-12 and GW6-12, with a groundwater level of 15.08 mAHD and 12.71 mAHD, respectively, and lowest at GW4-12, with a level of 4.33 mAHD. Groundwater levels across the site generally remained quite consistent when compared with the topographic conditions.

Figure 6-3 illustrates the groundwater contours in June 2017 (mid-dry season). During this sampling period, SWLs were measured at 15 of the 12 m bores. In comparison with the January 2017 samples, the reduced number of samples taken skews the map slightly, and are not considered representative of the entire site's groundwater behaviour during the dry season. However, similar trends are observed to that of the wet season. Groundwater levels were highest at GW6-12, with a groundwater level of 11.03 mAHD and lowest at GW4-12, with a level of -2.24 mAHD. The map illustrates a steep drop in groundwater levels during the dry season, from the centre of the site, towards the western, eastern and north-eastern boundaries.

Comparison between the levels of GW6-12 in both wet and dry seasons, indicate the potential for artificially elevated groundwater levels during the dry season (difference of almost 1.7 m), compared with a significant change in groundwater levels in GW4-12 between seasons of approximately 6.5m. Given the topographic positioning of GW10-12 (i.e. located on higher topography at the southern boundary of the site), the seasonal variation observed is to be expected.

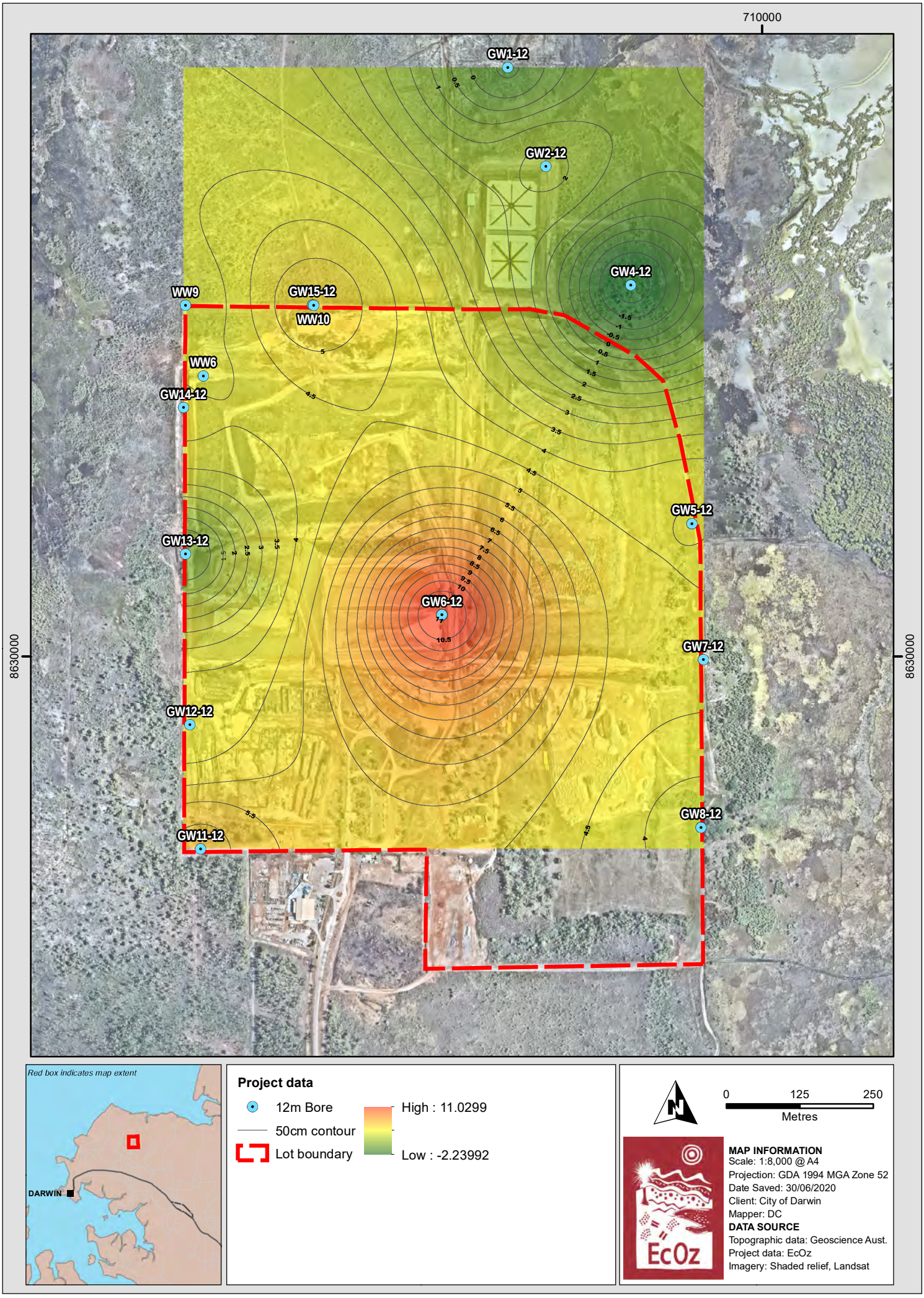
It is likely that groundwater mounding is also present, which can be attributed to the shape of the landfill cells. The presence of a shallow groundwater table and overflowing of some bores is resulting in groundwater mixing with leachate at surface level in some areas of the site. Figures 3 to 6 in the *Shoal Bay Site Conceptual Site Model Report,* written by URS (2016), highlight certain areas where this could be occurring. The report also highlights areas where inferred leachate affected groundwater is present across the site, i.e. underneath Stages 1, 2 and 3 of the landfill.

Leachate migration from the site is possible, considering the topographic conditions of SBWMF and historic landfilling activities on the western boundary of the site. Where groundwater is flowing along the eastern and north-eastern boundaries, those areas would also be of interest in regards to leachate detection and monitoring. Given the sensitive receiving environments for stormwater runoff and groundwater flow, outside of the SBWMF's boundaries (i.e. bushland and Leanyer Swamp), the results of Section 7 are crucial in determining the extent of (if any) leachate migration.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20054 - Shoal bay data review and report\01 Project Files\Figure X-X. January 2017.mxd

Figure 6-2. Map of groundwater level contours in mAHD for January 2017 (mid-wet season).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20054 - Shoal bay data review and report\01 Project Files\Figure X-X. June 2017.mxd

Figure 6-3. Map of groundwater level contours in mAHD for June 2017 (mid-dry season).

7 DATA REVIEW

The following data review is divided into leachate, surface water and groundwater. The leachate monitoring data is discussed first, in order to characterise leachate in the various landfills at the SBWMF so that this may then be used in identifying the presence of leachate in surface water and groundwater at the site. In particular, the leachate section identifies the key parameters that are elevated in, and unique to, the leachate as opposed to natural water sources (such as natural groundwater or seawater intrusion, which can also be elevated in an array of naturally-occurring dissolved constituents).

For each section (leachate, surface water, groundwater), each parameter is discussed sequentially, starting with physical parameters, then dissolved metals, nutrients, anions and cations, PFAS and hydrocarbons. The discussion of each parameter includes an outline of the relative concentrations measured at each site, comparisons to assessment criteria (where relevant), and any seasonal or long-term trends in concentrations. The results of this analysis are then summarised at the end of each of the leachate, surface water and groundwater sections. This includes highlighting any potential environmental concerns, recommended management actions or changes to the water quality monitoring program.

Median values are used when discussing each parameter in the sections below, due to the large volume of data collected over the July 2016 to March 2020 monitoring period and to screen-out outlier concentrations.

All graphs depicting the seasonal and long-term trends in water quality parameters discussed in the sections below are provided in Appendix B.

7.1 Leachate characterisation

Direct sampling of leachate is undertaken for the monitoring program at eight sites; as detailed in Table 4-2 and shown in Figure 2-1. The Stage 3/4 landfill is represented by the leachate dewatering points DW2, DW3 and TC Sump. The Stage 5 landfill is represented by the leachate dewatering points DW5 and DW6; although these two sites were only added to the monitoring program in June 2019 and November 2019 respectively, following establishment of the Stage 5 landfill. The two leachate storage ponds are represented by LP01 and LP02 respectively. The site LMP02, is the sump at the end of the drain that captures leachate seepage and surface water runoff from the Stage 1 and Stage 2 landfills.

Note that during the period September 2017 to June 2019, EcOz was advised not to sample the leachate sites DW2, DW3, TC Sump, LP01 and LP02, as these were being sampled by a different contractor as part of an investigation into leachate management options. EcOz has since been provided with data from September 2017 to March 2018, which has been included in this data review. EcOz has not been able to obtain data between April 2018 and June 2019 within this period for these five sites, and as such, there is a gap in the data shown in the graphs.

Parameters not discussed:

The results for the parameters listed below are not presented or discussed further in the leachate section; to see the data for these parameters refer to the SBWMF water quality monitoring database, which contains all monitoring results for all groundwater, surface water and leachate sites since monitoring began in July 2016. All original field data and laboratory documentation (including chain of custody, sample receipt notification, certificate of analysis and quality control documentation) was emailed to CoD following each monitoring round.

Polychlorinated biphenyls (PCBs) were always below the laboratory limit of reporting (LOR) at all leachate sites during all sampling rounds.

Nitrate (NO_3) concentrations were measured in leachate samples as per the URS (2016a) water monitoring plan requirements, but were extremely variable between sampling occasions, ranging from below detection, to several hundred mg/L at some sites. The laboratory also analysed and reported nitrite (NO_2) concentrations along with NO_3 concentrations, however only NO_3 concentrations were transferred into the

SBWMF database given NO_3 is used in the L/N ratio leachate indicator (see Section 4.6 above). NO_2 is not listed as a parameter in the URS (2016a) water monitoring plan. This is unfortunate, as a review of a number of the raw laboratory reports reveals that NO_2 often makes up a significant proportion of the oxidised nitrogen species in the leachate samples. Therefore, it would be misleading to make inferences regarding oxidised nitrogen species based only on the NO_3 concentrations.

In order to derive meaningful conclusions regarding oxidised nitrogen, the nitrate+nitrite (NO_3+NO_2; referred to as NOx) concentrations would be required. As such, the NO_3 concentrations for the leachate sites are not included in the discussion below, apart from where it is used in the L/N ratio.

Filterable reactive phosphorus (FRP) was only measured at all leachate monitoring sites once during the monitoring period i.e. June 2019, and there is little value in using data from only one sampling round in this data review.

Total organic nitrogen (TON) and results are highly variable, and the high concentrations of the many different chemical constituents present in the leachate samples means the laboratory LOR is often raised significantly due to sample matrix interferences. It is not possible to derive meaningful conclusions from this data.

Cyclotrimethyne trinitramine (RDX) and **trinitrotoluene (TNT)** have only been analysed twice at all leachate sample sites since monitoring began in July 2016; i.e. January 2017 and February 2020. On both these occasions, all concentrations were below the respective LORs.

Chromium exists in two different forms: **trivalent (III) chromium and hexavalent (VI) chromium**, when dissolved in water. Chromium (VI) is more toxic than chromium (III) (see Section 8.3.7 of the ANZECC 2000 guidelines for more detail), and a lower ANZECC (2000) trigger value is specified for chromium (VI) compared to chromium (III) i.e. trigger values are 0.02 and 0.049 mg/L respectively. No trigger value is specified for the combined sum of both chromium species.

The quarterly and annual leachate sample analysis suite currently includes chromium (III) and chromium (VI) speciation. The combined sum of all dissolved chromium species present is also provided in all raw laboratory analysis reports; although only the speciated chromium (VI) and chromium (III) concentrations have to date been transferred into the SBWMF water quality monitoring database.

Unfortunately, the laboratory analytical method for chromium speciation is very sensitive to sample matrix interference. The high concentrations of the many different chemical constituents present in the leachate samples means the laboratory LOR is always raised. For both chromium (VI) and chromium (III), the LOR was raised to between 0.1 and 1.0 mg/L for all samples collected from all leachate sites between July 2016 and March 2020 (data not reproduced in this report – see the SBWMF water quality monitoring database). This was except for LMP02, where the LOR was often the standard 0.01 mg/L.

All chromium (VI) results for all leachate sites during the monitoring period were below the various LOR's. However, given these LOR's were higher than the ANZECC (2000) trigger value of 0.02 mg/L, it cannot be determined if chromium (VI) concentrations at the leachate sites are above the trigger value. This was except for LMP02, where the LOR was mostly 0.01 mg/L (but sometimes up to 0.1 mg/L). Therefore, for the times where the LOR was 0.01 mg/L at this site, it can be confirmed the concentration was below the ANZECC (2000) trigger value.

Similarly, for chromium (III), most concentrations were below the LOR's and it cannot be determined if these chromium (III) concentrations are above the ANZECC (2000) trigger value of 0.049 mg/L. Chromium (III) concentrations however, were at times high enough to be above the LOR's and therefore, confirmed as being above the trigger value.

In contrast to chromium speciation analysis, the analysis of all dissolved chromium (combined sum of both species) is less affected by matrix interferences. All combined chromium concentrations measured during the monitoring period at all leachate sites were above the LOR, which remained at the standard 0.001 mg/L. For samples where the chromium (III) concentration was above the LOR, comparison with the combined sum of both chromium species concentrations for this sample indicates the majority of chromium present is chromium (III). Given the combined sum of chromium data has a low enough LOR for all samples to record

a concentration, these concentrations were extracted from the original laboratory records (given they were not available in the SBWMF database) and are now discussed below in lieu of any useful chromium (III) and chromium (VI) data.

7.1.1 Physical parameters

pH:

Median pH's for the five leachate sites (see Table 7-1) range from neutral at LMP02 (7.00), to slightly alkaline at LP01 and LP02 (8.13 and 8.20 respectively).

Over the July 2016 to March 2020 monitoring period, all leachate site pH's predominantly remained within the Darwin Harbour water quality objective range of 6.0 to 8.5, with no sites showing evidence of an increasing or decreasing trend.

LMP02 is the only site with a seasonal pattern in pH concentrations. The pH at this site gradually rises (becomes more alkaline) during the dry season, with the highest concentrations typically occurring during the late dry season (September), and lowest during the wet season (December to March). This is likely reflecting the changing relative proportions of surface water runoff to groundwater seepage reporting to this site, where:

- Fresh rainwater and runoff, which has had little contact time with the buried Stage 1 and Stage 2 landfill materials is slightly acidic
- Infiltrated surface water and groundwater seepage that has had more contact with buried landfill materials is slightly alkaline.

Electrical conductivity (EC):

The Stage 3/4 landfill leachate site DW3 records the highest median EC i.e. 25,076 µS/cm (see Table 7-1). This is followed by the other Stage 3/4 landfill leachate sites (DW2 and TC Sump) and Stage 5 landfill leachate sites (DW5 and DW6), with median ECs ranging between 18,491 and 22,361 µS/cm. The leachate pond sites LP01 and LP02 are comparatively lower (13,401 and 15,733 µS/cm respectively), and LMP02 has the lowest median EC (3,890 µS/cm).

Over the July 2016 to March 2020 monitoring period, EC concentrations measured at each leachate site were variable from month to month, and none of the sites showed clear evidence of a long-term increasing or decreasing trend.

LMP02 is the only site with a seasonal pattern in EC concentrations. Similarly, to pH, the EC at this site gradually increases during the dry season, with the highest concentrations typically occurring during the late dry season (September), and lowest during the wet season (December to March). Also, as for pH, this is likely reflecting the changing relative proportions of surface water runoff (with lower EC) to groundwater seepage (with higher EC due to contact time with landfill material) reporting to this site.

Dissolved oxygen (DO):

DO concentrations are almost always less than 50% saturation at all eight leachate monitoring sites. Median DO concentrations range between 7 and 28% saturation (Table 7-1).

DO is low in leachate because of the high oxygen demand of the landfill material it is in contact with i.e. from the breakdown of organic matter and oxidisation of wastes. Also, the leachate, whilst within the landfill, has been out of contact with oxygen in the atmosphere.

Over the July 2016 to March 2020 monitoring period, DO concentrations measured at each leachate site were highly variable from month to month, and none of the sites showed clear evidence of a long-term increasing or decreasing trend, or seasonal pattern.

Temperature:

Temperatures measured in leachate at each site, over each year, follow the expected seasonal pattern of lowest during the dry season (May to August) and highest during the early to mid-wet season (November to

February). During any one monitoring round however, DW3 usually records the highest temperature (median temperature 36.5°C) compared to the other sites (Table 7-1). This is followed by the other Stage 3/4 landfill leachate sites (DW2 and TC Sump) and Stage 5 landfill leachate sites (DW5 and DW6), with median temperatures ranging from 32.2 to 35.7°C. The leachate pond sites LP01, LP02, and sump site LMP02 usually record the lowest temperature of all the sites, with median temperatures between 28.9 to 29.6°C.

These results are indicating the Stage 3/4 and Stage 5 landfill cells are more readily heated by the sun and/or from the breakdown of waste materials compared to the leachate ponds and the water reporting to LMP02.

Table 7-1. Leachate site median physical parameter concentrations calculated for all data collected July 2016 – March 2019.

Parameter	Units	LMP02	DW3	DW2	TC Sump	DW5	DW6	LP01	LP02
pH	pH units	7.00	7.76	7.87	7.76	7.97	7.93	8.13	8.20
EC	µS/cm	3,890	25,076	20,902	18,145	18,491	22,361	15,530	16,350
DO	%sat	12	7	18	9	25	28	10	17
Temp	°C	29.6	36.5	34.1	32.2	35.7	35.4	28.9	29.3

7.1.2 Dissolved metals

Cadmium:

Dissolved cadmium concentrations are almost always below the LOR (i.e. <0.001), and always below the ANZECC (2000) trigger value of 0.014 mg/L at all leachate sites during all sampling rounds for the July 2016 to March 2020 monitoring period. This is likely not a true reflection of cadmium concentrations in the leachate given very high dissolved cadmium concentrations are observed in some groundwater bores; see Section 7.6 below. Possibly in the leachate, given the pH and high amounts of organic and suspended material, cadmium is bound to this material, and is not in the dissolved phase. Therefore, the cadmium would be filtered-out during sample preparation prior to analysis. Measuring total (unfiltered) cadmium in the samples in future may reveal very high cadmium levels in the leachate.

Chromium:

DW3 records the highest median chromium concentration (0.739 mg/L), with the next highest median recorded at LP02 (0.493 mg/L). The other leachate sites record medians ranging between 0.215 and 0.394 mg/L (Table 7-2), except for LMP02, which records lower chromium concentrations and a median of 0.007 mg/L.

Based on the available July 2016 to March 2020 monitoring data, all chromium concentrations measured at all sites, were above the chromium (III) ANZECC (2000) trigger value. This is except for LMP02, which always recorded concentrations below the trigger value.

The chromium data for LMP02 indicates a seasonal trend, where the highest concentrations generally occur during the mid to late dry season (June – September) and the lowest concentrations during the mid-wet season (January – March). The other sites do not show clear evidence of a seasonal trend, although concentrations at DW3 tend to be higher during the dry season and lower during the wet season, whereas the leachate pond sites LP01 and LP02 tend to be highest during the wet season and lowest during the dry season.

Chromium concentrations do not appear to be increasing or decreasing over the long-term, at any of the leachate sites, based on the available data.

Copper:

Copper concentrations in samples from the Stage 3/4 landfill leachate sites DW3 and DW2 are typically

several times higher than the other sites (Table 7-2). The median copper concentration for DW3 and DW2 is 0.147 and 0.208 mg/L respectively, compared to the next highest median concentration of 0.049 mg/L for the southern leachate pond LP02.

Copper concentrations are lower in the northern leachate pond LP01 (median concentration 0.020 mg/L), compared to the southern leachate pond LP02. Copper concentrations in the Stage 3/4 landfill leachate site TC Sump (median concentration 0.033 mg/L) are also lower compared to the other Stage 3/4 landfill sites DW3 and DW2.

The Stage 5 landfill leachate sites DW5 and DW6, have only been tested for dissolved metals up to three times since these sites were added to the monitoring program in late 2019. Based on this limited data, DW5 records higher concentrations compared to DW6, with median concentrations of 0.042 and 0.017 mg/L respectively.

LMP02 records low copper concentrations compared to the other leachate sites, with a median of 0.001 mg/L. Concentrations at this site are often below the LOR i.e. <0.001 mg/L.

Based on the available July 2016 to March 2020 monitoring data, all copper concentrations measured at all leachate sites were above the ANZECC (2000) trigger value of 0.003 mg/L. This was except for LMP02, where only 25% of concentrations measured were above the trigger value; all of these occurring during the early to mid-wet season (October – January).

Copper concentrations do not appear to be increasing or decreasing over the long-term, at any of the leachate sites, based on the available data. Seasonal trends are also not evident at any of the sites, apart from the higher concentrations at LMP02 during the early to mid-wet season.

Iron:

Iron is commonly present in natural waters and is an essential trace element for plants and animals. The ANZECC (2000) guidelines do not specify trigger values for iron due to the lack of data, although it is noted that adverse biological effects may occur at high concentrations above natural background levels.

Leachate samples are analysed for two different forms of iron: ferrous iron (Fe^{2+}) and ferric iron (Fe^{3+}). These are the two most common oxidisation states of iron in water, although other forms may be present in organic and inorganic wastewater streams. In oxidised waters, iron is generally present in the ferric iron (III) state, whereas in reducing waters, the ferrous iron (II) form persists. Ferrous iron (II) is more soluble compared to ferric iron (III), which will often precipitate as a ferric hydroxide floc unless the water is very acidic (<pH 3.5).

LMP02 records the highest iron (II) concentrations, with a median of 10.6 mg/L (Table 7-2). This is followed by the Stage 3/4 landfill leachate sites TC Sump, with a median of 8.6 mg/L, and DW3, with a median of 7.5 mg/L. Almost all the iron present at LMP02 is ferrous iron (II); given the median ferric iron (III) concentration is only 0.05 mg/L. Similarly, the majority of iron at the DW3 and TC Sump sites is ferrous iron (II), with a median ferric iron (III) concentration of 1.71 and 3.27 mg/L respectively, i.e. ferrous iron (II) comprises 81% of iron at DW3, and 72% of iron at TC Sump. These results are indicating that the water at these sites is iron-rich, and has come from a reducing/anaerobic environment.

The leachate pond sites LP01 and LP02 record comparatively lower iron concentrations, with median ferrous (II) iron concentrations of 3.0 and 4.2 mg/L respectively. Ferric iron (III) comprises a greater proportion of iron at these sites, with medians of 3.90 and 3.8 mg/L respectively, i.e. ferrous iron (II) comprises only 43% of iron at LP01 and 53% at LP02. These results are indicating the leachate ponds are a comparatively more oxidised environment compared to the source of water to LMP02, DW3 and TC Sump.

DW2 records the lowest iron concentrations of all the sites, with a median iron (II) concentration of 1.76 mg/L and median iron (III) concentration of 0.86 mg/L.

Conclusions cannot be drawn from the iron concentrations so far measured at the Stage 5 landfill leachate sites DW5 and DW6. Only three concentrations have so far been measured at DW5 (June 2019, January 2020 and February 2020) and two at DW6 (January and February 2020). Iron (II) and iron (III) concentrations were highly variable between these sampling occasions and the calculated median may not

be representative.

The ferrous iron (II) data for LMP02 indicates a seasonal trend, where the highest concentrations generally occur during the wet season (January – April) and lowest at the end of the dry season (September - December). This trend is inverse to the seasonal trend of other dissolved metals at this site. Ferrous iron (II) is also higher at this site compared to the landfill leachate sites. This is indicating that this parameter is not directly related to leachate inputs and is possibly affected by surface water inputs and interactions in the environment.

The other leachate sites do not show clear evidence of a seasonal trend in ferrous iron (II).

It is difficult to discern any clear seasonal trends in ferric iron (III) concentrations at any of the sites including LMP02.

Iron concentrations do not appear to be increasing or decreasing over the long-term, at any of the leachate sites, based on the available data.

Manganese:

Manganese concentrations are relatively similar across the leachate sites, with median concentrations ranging from 0.072 mg/L at LMP02 to 0.172 mg/L at LP02 (Table 7-2). This is except for the Stage 5 landfill sites DW5 and DW6, which record concentrations higher than this, with medians of 0.200 and 0.367 mg/L respectively; although this is calculated using only the few measurements available for these two sites.

Based on the available July 2016 to March 2020 monitoring data, almost all manganese concentrations measured at all leachate sites were above the ANZECC (2000) trigger value of 0.08 mg/L. This was except for LMP02, where only 42% of concentrations measured were above the trigger value; all of these occurring during the early to mid-wet season (December to February).

Manganese concentrations do not appear to be increasing or decreasing over the long-term at any of the leachate sites, based on the available data. Seasonal trends are also not evident at any of the sites, apart from the higher concentrations at LMP02 during the early to mid-wet season.

Nickel:

Nickel concentrations are highest at the Stage 3/4 landfill sites (DW3, DW2 and TC Sump) and at LP02, with median concentrations ranging between 0.199 and 0.291 mg/L (Table 7-2). LP01 concentrations are lower, with a median of 0.166 mg/L. The Stage 5 landfill sites DW5 and DW6 also record lower concentrations, with medians of 0.120 and 0.075 mg/L respectively; although this is calculated using only the few measurements available for these two sites. LMP02 records the lowest median nickel concentration of all the leachate sites (0.023 mg/L).

Based on the available July 2016 to March 2020 monitoring data, the majority of nickel concentrations measured at DW3, DW2, TC Sump and LP02 were above the ANZECC (2000) trigger value of 0.2 mg/L. Whereas the majority of nickel concentrations at LP01 were below the trigger value, and all concentrations at LMP02 were below the trigger value.

A seasonal trend is evident at all sites, where nickel concentrations increase over the dry season and are highest at the end of the dry season (September – October), and lowest during the mid-wet season (January – February). Nickel concentrations do not appear to be increasing or decreasing over the long-term at any of the leachate sites, based on the available data.

Lead:

Lead concentrations are highest at the Stage 3/4 landfill sites (DW3 and TC Sump) and at LP02, with median concentrations of 0.044, 0.034 and 0.032 mg/L respectively (Table 7-2). LP01 and DW2 concentrations are lower, with a median of 0.018 mg/L. The Stage 5 landfill sites DW5 and DW6 also record low concentrations, with medians of 0.005 and 0.003 mg/L respectively; although this is calculated using only the few measurements available for these two sites. LMP02 has always recorded lead concentrations below the LOR (<0.001 mg/L) since monitoring began in July 2016.

Based on the available July 2016 to March 2020 monitoring data, all lead concentrations measured at DW3 were well above the ANZECC (2000) trigger value of 0.0066 mg/L. All concentrations were also above the trigger value at TC Sump and LP02, except for one isolated occurrence each, where it was below the trigger value. At DW2, LP01 and LP02, all lead concentrations were above the trigger value in 2016 and 2017; however, concentrations at these sites were lower in 2019 and 2020, and mostly below the trigger value.

Distinctive seasonal trends are not evident in the available data of any sites. There is however a general trend (not associated with seasons) of increasing concentrations at DW3, DW2, TC Sump, LP01 and LP02 between September 2016 and September 2017. Then, concentrations at these sites are generally lower during 2019 and 2020.

Zinc:

Zinc concentrations are highest at DW3, with a median of 0.851 mg/L. This is followed by LP02, with a median of 0.675 mg/L. DW2, TC Sump and DW5 have similar concentrations, with medians ranging between 0.449 and 0.495 mg/L. LP01 and DW6 have lower concentrations (medians of 0.312 and 0.231 mg/L respectively), and LMP02 has the lowest concentrations, with a median 0.016 mg/L.

Based on the available July 2016 to March 2020 monitoring data, all zinc concentrations measured at all sites (except LMP02) were above the ANZECC (2000) trigger value of 0.023 mg/L. At LMP02, only 32% of zinc concentrations were above the trigger value; all these occurred during the early wet season, with the highest concentrations in December.

Distinctive seasonal trends are not evident in the available data of any sites, apart from that mentioned above for LMP02, where the concentrations at this site are higher during the early wet season. Concentrations at DW3, DW2, TC Sump, LP01 and LP02 do however, appear to decrease over the long-term, with concentrations measured during 2019 and 2020 being generally lower than between September 2016 and August 2017.

Table 7-2. Leachate site median dissolved metal concentrations calculated for all data collected July 2016 – March 2019

Parameter	Units	Trigger value	LMP02	DW3	DW2	TC Sump	DW5	DW6	LP01	LP02
Cadmium	mg/L	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.049	0.007	0.739	0.363	0.285	0.394	0.215	0.297	0.493
Copper	mg/L	0.003	0.001	0.147	0.208	0.033	0.042	0.017	0.020	0.049
Iron (II)	mg/L	-	10.60	7.47	1.76	8.58	5.50	5.58	3.00	4.20
Iron (III)	mg/L	-	0.05	1.71	0.86	3.27	1.15	6.18	3.90	3.78
Manganese	mg/L	0.08	0.072	0.116	0.100	0.180	0.200	0.367	0.133	0.172
Nickel	mg/L	0.2	0.023	0.291	0.199	0.254	0.120	0.075	0.166	0.250
Lead	mg/L	0.0066	<0.001	0.044	0.018	0.034	0.005	0.003	0.018	0.032
Zinc	mg/L	0.023	0.016	0.851	0.466	0.449	0.495	0.231	0.312	0.675

Median concentrations above the ANZECC (2000) trigger value for 90% species protection in marine water shaded in red.

7.1.3 Nutrients, organic content and oxygen demand

Ammonia (NH_3):

Leachate samples are analysed for total ammonia as nitrogen (denoted as NH_3-N). The term 'ammonia' refers to two chemical species of ammonia that are in equilibrium in water: the un-ionised ammonia, NH_3, and ionised ammonium ion, (NH_4^+) according to the equation $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$. The proportion of the two chemical forms NH_3 and NH_4^+ varies with the physico-chemical properties of the water, particularly pH and temperature. In alkaline (high pH) solutions, the predominant species is ammonia (NH_3), while ammonium (NH_4^+) predominates at lower pH.

The L/N ratio indicator (see Section 4.6 above), requires the concentration of ammonium ions (NH_4^+). As such, the laboratory is requested to report the proportion of NH_3-N occurring as NH_4^+. In order to calculate this, the laboratory is provided with the field-measured pH and temperature of the sample point, at the time of sampling. Given NH_4^+ is a calculated concentration based on the laboratory-analysed NH_3-N, only NH_3-N is discussed here. The L/N ratio results are discussed in Section 7.1.4 below.

Ammonia concentrations are high in leachate at all sites (Table 7-3). Median concentrations for the Stage 3/4 landfill leachate sites range from highest at DW3 with 2125 mg/L down to 1305 mg/L at TC Sump. This is between 1000 and 1800x higher than the ANZECC (2000) trigger value applying to the SBWMF site i.e. 1.2 mg/L. The leachate pond medians at LP01 and LP02 are lower (714 and 1020 mg/L respectively) compared to the Stage 3/4 landfill sites; equating to greater than 600x the trigger value. LMP02 records the lowest ammonia concentrations of all the leachate sites; although the median is 196 mg/L, which is still 163x above the trigger value. The Stage 5 landfill sites DW5 and DW6, record medians in the same range as the Stage 3/4 landfill i.e. 1860 and 1415 mg/L respectively; although this is based on the very few measurements available for these two sites.

Based on the available July 2016 to March 2020 monitoring data, LMP02 is the only site showing a distinct seasonal trend in ammonia concentrations. The ammonia at this site gradually increases over the dry season, with the highest concentrations typically occurring during the late dry season (September), and lowest during the wet season (December to March). This is likely reflecting the changing relative proportions of surface water runoff (which is lower in ammonia) to groundwater seepage (which is higher in ammonia due to contact with landfill material) reporting to this site, as explained above for pH and EC.

Ammonia concentrations do not appear to be increasing or decreasing over the long-term at any of the leachate sites, based on the available data.

Total organic carbon (TOC):

Total organic carbon (TOC) is the amount of carbon existing in organic compounds in the water, including in both dissolved and particulate forms, and from either natural or synthetic sources. ANZECC (2000) does not specify guideline values for TOC given this is not strictly a toxicant, although high concentrations can indicate highly polluted water and high inputs of organic matter to waterways can lead to eutrophication.

DW3 records the highest median TOC concentration (2050 mg/L), followed by the other Stage 3/4 landfill sites DW2 and TC Sump with medians of 1240 and 1090 mg/L respectively (Table 7-3). The Stage 5 landfill sites DW5 and DW6 also record medians similar to the Stage 3/4 landfill sites (medians 1500 and 1030 mg/L respectively); although these medians are based on the limited data available for these two sites. The leachate ponds LP01 and LP02 have lower TOC concentrations (medians of 854 and 1025 mg/L respectively). LMP02 has the lowest TOC concentrations with a significantly lower median of 97 mg/L.

Based on the available July 2016 to March 2020 monitoring data, LMP02 is the only site showing a distinct seasonal trend in TOC concentrations. The TOC at this site gradually increases during the dry season, with the highest concentrations typically occurring during the late dry season (August to September), and lowest during the early wet season (December to January). This is likely reflecting the changing relative proportions of surface water runoff (which has lower TOC concentrations) to groundwater seepage (which is higher in TOC due to contact with landfill material) reporting to this site, as explained above for pH and EC.

TOC concentrations do not appear to be increasing or decreasing over the long-term at any of the leachate sites, based on the available data.

Chemical oxygen demand (COD) and biochemical oxygen demand (BOD):

Chemical oxygen demand (COD) is an indicative measure of oxidisable pollutants in water; including organic matter and inorganic chemicals such as ammonia and nitrite. Biochemical oxygen demand (BOD) is also an indicative measure of oxidisable components in water, but only that which is oxidised by bacteria and other microorganisms whilst they decompose organic matter under aerobic conditions. Both COD and BOD indicate the potential reduction in dissolved oxygen caused by wastewater if it was to enter a natural waterway.

DW3 records by far the highest COD concentrations with a median of 6250 mg/L (Table 7-3). DW2, TC Sump, DW5, DW6 and LP02 record concentrations within a similar range, with medians for these sites ranging between 3460 and 4140 mg/L. LP01 records relatively lower concentrations (median of 2650 mg/L) and LMP02 records significantly lower concentrations (median of 298 mg/L).

BOD concentrations are similarly highest at DW3 (median of 275 mg/L) compared to the other sites, although not to the same degree as COD (Table 7-3). Median concentrations of the sites with the next highest concentrations, DW2 and TC Sump, are 215 and 149 mg/L respectively. The leachate pond sites LP01 and LP02 are relatively lower (64 and 107 mg/L respectively) and LMP02 is the lowest (20 mg/L). The Stage 5 landfill sites DW5 and DW6 only have one BOD concentration recorded during the monitoring period, which is insufficient to include in this site comparison.

Based on the available July 2016 to March 2020 monitoring data, LMP02 shows a distinct seasonal trend in COD and BOD concentrations. The COD and BOD at this site is generally highest during the mid to late dry season (July to October) and lowest during the early wet season (December-January). This is likely reflecting the changing relative proportions of surface water runoff (which has lower COD and BOD) to groundwater seepage (which has a higher COD and BOD due to contact with landfill material) reporting to this site, as explained above for pH and EC.

The Stage 3/4 landfill sites DW3, DW2 and TC Sump show evidence of a seasonal trend of generally higher concentrations during the dry season and lower concentrations during the wet season. The leachate pond sites LP01 and LP02 do not appear to have a seasonal pattern based on the available data; although LP01 shows an increasing trend between July 2016 and August 2017 unrelated to the seasons. None of the other sites appear to be increasing or decreasing over the long-term, based on the available data.

Table 7-3. Leachate site median nutrient, organic content and oxygen demand concentrations calculated for all data collected July 2016 – March 2019.

Parameter	Units	Trigger value	LMP02	DW3	DW2	TC Sump	DW5	DW6	LP01	LP02
Ammonia	mg/L	1.2	196	2125	1680	1305	1860	1415	714	1020
TOC	mg/L	-	97	2050	1240	1090	1500	1030	854	1025
BOD	mg/L	-	20	275	215.5	149	276	216	64	107
COD	mg/L	-	298	6250	3875	3460	4140	3930	2650	3860

Median concentrations above the ANZECC (2000) trigger value for 90% species protection in marine water shaded in red – where a trigger value is available.

7.1.4 Anions, cations and L/N ratio

Major anion and cation concentrations:

Major anion (sulfate, chloride, alkalinity) and major cation (calcium, magnesium, potassium and sodium) concentrations recorded in the leachate monitoring sites are summarised as median concentrations in Table 7-4. DW3 records the highest chloride, alkalinity, potassium and sodium concentrations. The other sites DW2, TC Sump, DW5, DW6, LP01 and LP02 record concentrations of these anions and cations within a similar range. LMP02 records significantly lower concentrations for these anions and cations.

The anions and cations not listed above i.e. sulfate, calcium and magnesium, the newer Stage 5 landfill sites DW5 and DW6 record the highest concentrations.

Based on the available July 2016 to March 2020 monitoring data, LMP02 shows a distinct seasonal trend in chloride, alkalinity, potassium and sodium concentrations. These anions and cations at this site are generally highest during the dry season and lowest during the wet season. Similarly, for most other contaminants, this is likely reflecting the changing relative proportions of surface water runoff (which has lower contaminants) to groundwater seepage (which has higher contaminants due to contact with landfill material) reporting to this site, as explained above for pH and EC.

The Stage 3/4 landfill sites DW3, DW2 and TC Sump show evidence of a seasonal trend of generally higher chloride, alkalinity, potassium and sodium concentrations during the dry season, and lower concentrations during the wet season. These sites do not show a seasonal trend for sulfate, calcium and magnesium.

The leachate pond sites LP01 and LP02 do not appear to have a seasonal pattern based on the available data, and DW5 and DW6 do not have enough data to indicate any seasonal patterns.

None of the sites appear to be increasing or decreasing over the long-term, based on the available data.

L/N ratios:

All six ions required to calculate the L/N ratio (see Section 4.6 above) are analysed on a quarterly basis. The L/N ratio values calculated for each of these quarterly rounds, for each site, have been relatively consistent throughout the July 2016 to March 2020 monitoring period, with limited variation between monitoring rounds.

The median L/N ratio calculated for each site is provided in Table 7-4. The ratio values are highest at DW5, DW6, DW3, DW2 and TC Sump sites in that order ranging from 164 down to 100. The LP01, LP02 and LMP02 sites record similar L/N ratios with medians of 88. Significantly, the LMP02 site, has a relatively high L/N ratio despite having lower contaminant concentrations compared to the other leachate sites (see sections above). This is showing that the contaminants that are present, are derived from landfill leachate, most likely from the seepage of groundwater from the Stage 1 and Stage 2 landfills into the drain that reports to this site.

Table 7-4. Leachate site median anion and cation concentrations and L/N ratios calculated for all data collected July 2016 – March 2019.

Parameter	Units	LMP02	DW3	DW2	TC Sump	DW5	DW6	LP01	LP02
Sulfate as SO_4	mg/L	5	10	11	11	25	38	10	14
Chloride	mg/L	444	3090	2180	2340	2050	2300	1870	2180
Alkalinity as $CaCO_3$	mg/L	1190	9570	7206	6113	5400	4645	3335	4900
Calcium	mg/L	48	36	40	50	71	154	34	50
Magnesium	mg/L	19	40	53	47	59	130	40	48
Potassium	mg/L	117	934	678	681	732	800	600	760
Sodium	mg/L	294	2300	1930	1850	1290	1148	1460	1850
L/N ratio	mg/L	85	125	111	100	164	149	88	88

There are no ANZECC (2000) trigger values relating to anions and cations.

7.1.5 PFAS

PFAS:

PFAS concentrations have only been analysed in samples from the leachate sample sites on three occasions for this monitoring program: June 2019, October 2019 and January 2020. Based on this data (see SBWMF database) the following is concluded for the direct leachate sampling sites DW3, DW2, TC Sump, DW5 and DW6:

- PFAS concentrations are high. The sum of all 28 species analysed is on average 20 µg/L.
- The PFAS species PFBS comprises 58% of this, followed by PFHxA (15%), PFPeA (7.5%) and PFOA (6.4%). Twelve other PFAS species comprise the remaining 13%, and 12 are usually below the LOR.
- Significantly, the three PFAS species with guidance values in the PFAS NEMP (i.e. PFHxS, PFOS and PFOA) only comprise 11% of the total PFAS concentration. The average PFOS+PFHxS concentration (1.15 µg/L) is above the PFAS NEMP recreational water guidance

value (0.7 µg/L), but below the 90% species protection aquatic ecosystem value (2 µg/L). The average PFOA concentration (1.83 µg/L) is below the recreational water guidance value (5.6 µg/L).

The leachate pond sites (LP01 and LP02) also record high PFAS concentrations, with the sum of all 28 species analysed on average 10 µg/L at LP01 and 25 µg/L at LP02. Again, the most prevalent PFAS species is PFBS (average for both sites combined 9.1 µg/L), followed by PFHxA (average 2.05 µg/L) and PFOA (average 1.84 µg/L).

LMP02 records the lowest concentrations of the leachate sampling sites with an average sum of all 28 species of 2.8 µg/L. Of note is that the most prevalent PFAS species at this site is PFOS (average 0.85 µg/L), followed by PFHxS (average 0.51 µg/L) and PFOA (average 0.33 µg/L). This is likely reflecting the older landfill signatures i.e. seepage from the Stage 1 and Stage 2 landfills, which pre-date the phasing out of these PFAS species for use in products. Whereas the Stage 3/4 and Stage 5 landfills contain relatively less of these PFAS species, which are now being replaced by alternative chemicals in products that previously would have contained PFOS, PFOA and PFHxS. The average PFOS+PFHxS concentration at LMP02 (1.36 µg/L) is well above the PFAS NEMP recreational guideline, but remains below the applicable aquatic ecosystem guideline value.

There is not yet enough data to determine any seasonal or long-term trends in PFAS concentrations at any of the leachate sites.

7.1.6 Hydrocarbons

Total recoverable hydrocarbons (TRH):

All total petroleum (TPH) and total recoverable hydrocarbon (TRH) fractions are analysed in leachate samples, however only the TRH >C10—C40 fraction (sum) is transferred from laboratory reports and recorded in the SBWMF water quality monitoring database. As such, only this combined fraction concentration is discussed below. Note that no TPH or TRH data yet exists for the DW5 and DW6 sites and therefore, these are also not included in the discussion below.

DW3 records by far the highest TRH (sum) concentrations, with a median of 22,200 µg/L (Table 7-5). This is followed by DW2, TC Sump, LP02 and LP01, in that order. LMP02 records the lowest TRH concentrations, but these are still relatively high, with a median of 950 µg/L.

Based on the available July 2016 to March 2020 monitoring data, LMP02 is the only site showing a distinct seasonal trend in TRH concentrations. The TRH at this site gradually increases over the dry season and is lowest during the early to mid-wet season (November to February). This is likely reflecting the changing relative proportions of surface water runoff (which is lower in TRH) to groundwater seepage (which is higher in TRH due to contact with landfill material) reporting to this site, as explained above for pH and EC.

TRH concentrations do not appear to be increasing or decreasing over the long-term at any of the leachate sites, based on the available data.

Polycyclic aromatic hydrocarbons (PAHs):

A suite of 16 different PAHs are analysed in leachate samples, however only the sum concentration of all of them is transferred from laboratory reports and recorded in the SBWMF water quality monitoring database. As such, only the PAH sum is discussed below.

All PAH sum concentrations measured to date at DW5, DW6 and LP01 are below the LOR (i.e. <0.5 µg/L), and all concentrations, except one, are below the LOR at LP02. Similarly, most concentrations recorded at DW2 and TC Sump are below the LOR, with some occasional concentrations of up to 1.9 and 2.4 µg/L respectively.

Concentrations at DW3 are up to 4.8 µg/L with all of this comprising the PAH naphthalene. This is relatively low given the ANZECC (2000) trigger value for naphthalene is 90 µg/L.

Conversely to other contaminants, LMP02 records the highest PAH (sum) concentrations, with a median of 2.7 µg/L and highest concentration of 10.1 µg/L. All of this also comprising naphthalene and therefore still well below the ANZECC (2000) trigger value. The cause of these incongruously high naphthalene concentrations at LMP02, compared to the pattern in other contaminants at this site, are not known, but may be unique to the Stage 1 and 2 landfill sources of leachate to this site or the type of environment of this site, being a catchment drain leading to a sump (as opposed to a leachate dewatering well).

Based on the available July 2016 to March 2020 monitoring data, there is no clear evidence of any seasonal trends or long-term trends at any of the sites.

Benzene, toluene, ethylbenzene, xylene (BTEX):

Benzene, toluene, ethylbenzene and xylene (BTEX) are volatile aromatic hydrocarbons (i.e. TPH fraction C6-C9). All these hydrocarbon compounds are analysed in leachate samples, however only the sum concentration of benzene, toluene, ethylbenzene and xylene has been transferred from laboratory reports and recorded in the SBWMF database. This is unfortunate given the ANZECC (2000) guidelines include trigger values for benzene, toluene, ethylbenzene and xylene but not the sum of these. A brief review of the historic raw laboratory reports reveals that all these compounds are present in varying concentrations at varying times to make up the sum total BTEX concentration. Without spending time entering all this data, only the BTEX (sum) can be discussed below without comparison to any ANZECC (2000) trigger values.

DW3 and DW2 record by far the highest BTEX concentrations (medians of 247 and 178 µg/l respectively) followed by TC Sump, DW5 and DW6 with median concentrations between 28 and 86 µg/L. LP01, LP02 and LMP02 record negligible BTEX concentrations, with medians all less than 5 µg/L.

Based on the available July 2016 to March 2020 monitoring data, there is no clear evidence of any seasonal trends or long-term trends at any of the sites.

Phenols (total):

Phenols (total) are highest at DW3, TC Sump and DW5; all have medians above 0.96 µg/L. Whereas phenol concentrations at TC Sump, DW6, LP01 and LP02 are relatively low; medians all below 0.32 µg/L. LMP02 has always recorded phenols below the LOR i.e. <0.05 µg/L.

Based on the available July 2016 to March 2020 monitoring data, there is no clear evidence of any seasonal trends or long-term trends at any of the sites.

Table 7-5. Leachate site median hydrocarbon concentrations calculated for all data collected July 2016 – March 2019.

Parameter	Units	LMP02	DW3	DW2	TC Sump	DW5	DW6	LP01	LP02
TRH >C10-C40 (sum)	µg/L	950	22,200	16,400	6,900	-	-	4,890	7,520
PAH (sum)	µg/L	2.7	1.0	0.3	0.4	<0.5	<0.5	<0.5	<0.5
BTEX (sum)	µg/L	4	247	178	37	28	86	5	5
Phenols (total)	µg/L	<0.05	1.19	0.96	0.15	1.02	0.32	0.50	0.50

ANZECC (2000) trigger values are available for individual PAH, phenol and BTEX compounds but not for the combined sums of these compounds.

7.2 Summary of leachate characterisation

Contaminant concentrations are generally always highest at the Stage 3/4 landfill site DW3, followed by the other Stage 3/4 landfill sites DW2 and TC Sump. The leachate pond sites LP02 and LP01 have the next highest concentrations. The leachate drain from the Stage 1 and 2 landfills (LMP02) generally has the lowest contaminant concentrations given this site also receives surface water runoff that has not been in

contact with landfill wastes (see discussion below). There is not yet enough data to include the Stage 5 landfill leachate sites DW5 and DW6 in this comparison.

The following dot points summarise the typical water quality of leachate:

- pH ranges from neutral (7.00) to slightly alkaline (8.20).
- EC is very high, ranging between 18,000 and 25,000 µS/cm in leachate direct from the landfills, and between 13,400 and 16,000 µS/cm in the leachate ponds. The leachate collection drain LMP02 has a seasonal pattern in EC concentrations (high during dry season and low during wet season), with a median concentration of 4,000 µS/cm.
- DO concentrations are almost always less than 50% saturation at all eight leachate monitoring sites. Median DO concentrations range between 7 and 28% saturation.
- Temperatures follow the expected seasonal pattern of lowest during the dry season (May to August) and highest during the early to mid-wet season (November to February). At any one time, DW3 usually records the highest temperature (median temperature 36.5°C), followed by the other Stage 3/4 landfill leachate sites (DW2 and TC Sump) and Stage 5 landfill leachate sites (DW5 and DW6), with median temperatures ranging from 32.2 to 35.7°C. The leachate pond sites LP01, LP02, and sump site LMP02 usually record the lowest temperature of all the sites, with median temperatures between 28.9 to 29.6°C.
- Dissolved metal (chromium, copper, manganese, nickel, lead and zinc) concentrations are usually highest at DW3. This is followed by DW2, TC Sump, DW5 and DW6. The leachate ponds are comparatively lower, with the southern leachate pond (LP02) usually always recording higher concentrations than the northern leachate pond (LP01). All leachate sites (except LMP02) record dissolved metals concentrations well above the relevant ANZECC (2000) trigger value most of the time, and the median concentrations calculated for all these sites are all above the respective trigger values. Dissolved metal concentrations recorded at LMP02 are usually below the relevant ANZECC (2000) trigger values, with all medians below the respective trigger values.

  Seasonal trends in dissolved metal concentrations are evident at LMP02, with the highest concentrations generally occurring during the end of the dry season/early wet season. None of the other sites show clear evidence of seasonal trends in the available data, except for nickel, which is highest during the dry season and lowest during the wet season. Significant long-term increasing or decreasing concentration trends over the July 2016 to March 2020 monitoring period are not evident at any of the sites.
- Cadmium concentrations are almost always below the LOR (i.e. <0.001 mg/L) at all leachate sites during all monitoring rounds. This is likely not a true reflection of cadmium in the leachate. It may be that all the cadmium exists in the solid phase and/or sorbed onto the high amounts of suspended and organic material in the leachate. Given the samples are analysed for 'dissolved' metals, they are filtered prior to analysis. Potentially the cadmium is removed through the filtering process.
- Ferrous (II) and ferric (III) iron concentrations differ to those metals listed above, in that iron (II) concentrations were generally highest at LMP02 and iron (III) concentrations highest at DW6, LP01, LP02, and TC Sump. The seasonal trend in iron (II) concentrations at LMP02 is also counter to that of other contaminants, in that concentrations are highest during the wet season and lowest during the dry season.
- Ammonia concentrations are extremely high at all leachate sites. Concentrations are generally between 1,000 and 1,800 times the applicable ANZECC (2000) trigger value at the Stage 3/4 and Stage 5 landfill sites (DW3, DW2, TC Sump, DW5 and DW6). Concentrations are lower in the leachate ponds (LP02 and LP02); although still more than 600 times the trigger value. LMP02 records the lowest concentrations, but these are also still generally more than 163 times the trigger value.

LMP02 is the only site showing seasonal variation in concentrations, with highest concentrations during the late dry season and lowest during the wet season. None of the leachate sites show evidence of an increasing or decreasing trend in concentrations based on the available data for the monitoring period.

- TOC, COD and BOD concentrations are highest at DW3. TOC and BOD concentrations are comparatively lower (but still very high), at the other Stage 3/4 landfill sites (DW2, TC Sump) and Stage 5 landfill sites (DW5 and DW6). The concentrations of TOC and BOD at these four sites are within a similar range. TOC and BOD are comparatively lower at LP01 and LP02, followed by LMP02, with the lowest concentrations.

  COD is relatively lower than at DW3 (but still very high), and within a similar range at DW2, TC Sump, DW5, DW6, LP01 and LP02. Again, LMP02 records the lowest COD concentrations compared to the other leachate sites. LMP02 shows a seasonal trend of highest TOC, COD and BOD concentrations during the late dry season and lowest during the wet season. The only other seasonal trend identified in the TOC, COD and BOD data is higher COD and BOD concentrations during the dry season, and lower concentrations during the wet season at the Stage 3/4 landfill sites (DW3, DW2, TC Sump). The only long-term trend in concentrations (unrelated to seasons) was an increasing trend in COD and BOD at LP01 between July 2016 and August 2017.

- Major anion (sulfate, chloride, alkalinity) and major cation (calcium, magnesium, potassium and sodium) concentrations are highest at DW3. The other sites DW2, TC Sump, DW5, DW6, LP01 and LP02 record concentrations within a similar range. LMP02 records significantly lower concentrations.

  LMP02 shows a distinct seasonal trend in chloride, alkalinity, potassium and sodium concentrations with highest concentrations during the dry season and lowest during the wet season. The Stage 3/4 landfill sites DW3, DW2 and TC Sump also show evidence of a seasonal trend of generally higher chloride, alkalinity, potassium and sodium concentrations during the dry season, and lower concentrations during the wet season. These sites do not show a seasonal trend for sulfate, calcium and magnesium. None of the sites appear to be increasing or decreasing over the long-term, based on the available data.

- The L/N ratio values calculated for each site have been relatively consistent throughout the monitoring period, with limited variation between monitoring rounds. The L/N ratio values are highest at DW5, DW6, DW3, DW2 and TC Sump in that order, ranging from 164 down to 100. The LP01, LP02 and LMP02 sites record similar L/N ratios, with medians between 85 and 88. The LMP02 site has a relatively high L/N ratio despite having lower contaminant concentrations compared to the other leachate sites. This is showing that the contaminants that are present, are derived from landfill leachate, most likely from the seepage of groundwater from the Stage 1 and Stage 2 landfills into the drain that reports to this site.

- PFAS concentrations are high at all leachate sampling sites. At all sites except LMP02, the most prevalent PFAS species are PFBS, PFHxA, PFPeA and PFOA, in that order. Of these, only PFOA has a guidance value in the PFAS NEMP (i.e. only PFHxS, PFOS and PFOA have guidance values). Despite this, even though PFOS+PFHxS is not the most prevalent PFAS species, these sites still record concentrations of PFOS+PFHxS above the PFAS NEMP recreational water guidance value (but still remains below the 90% species protection for aquatic ecosystems guideline value).

  LMP02 records the lowest PFAS concentrations of the leachate sampling sites but of note is that the most prevalent PFAS species at this site are PFOS, PFHxS and PFOA, in that order. The average PFOS+PFHxS concentration is well above the PFAS NEMP recreational guideline. This is likely reflecting the older landfill signatures i.e. seepage from the Stage 1 and Stage 2 landfills, which pre-date the phasing out of these PFAS species for use in products. Whereas the Stage

3/4 and Stage 5 landfills contain relatively less of these PFAS species, which are now being replaced by alternative chemicals in products that previously would have contained PFOS, PFOA and PFHxS.

- In regards to hydrocarbons, TRH (sum) concentrations are the highest at DW3 (22,200 µg/L), followed by DW2, TC Sump, LP02 and LP01, in that order. LMP02 records the lowest TRH concentrations, but these are still relatively high, with a median of 950 µg/L. LMP02 is the only site showing evidence of a seasonal trend, with higher concentrations during the dry season and lower concentrations during the wet season.

  For BTEX (sum), DW3 and DW2 record the highest concentrations (medians of 247 and 178 µg/L respectively) followed by TC Sump, DW5 and DW6, with median concentrations between 37 and 86 µg/L. LP01, LP02 and LMP02 record negligible BTEX concentrations, with medians all less than 5 µg/L.

  Phenols (total) are highest at DW3, TC Sump and DW5; all have medians above 0.96 µg/L. Whereas phenol concentrations at TC Sump, DW6, LP01 and LP02 are relatively low; medians all below 0.32 µg/L. LMP02 has always recorded phenols below the LOR i.e. <0.05 µg/L.

  Contrary to TRH, BTEX and phenols, LMP02 records the highest PAH concentrations (up to 10.1 µg/L) followed by DW3 (up to 4.8 µg/L). All of this comprises the PAH compound naphthalene at both of these sites and therefore concentrations are all below the ANZECC (2000) trigger value for naphthalene of 90 µg/L. All the other sites record concentrations predominantly below the LOR. The cause of these incongruously high naphthalene concentrations at LMP02, compared to the pattern in other contaminants at this site, are not known, but may be unique to the Stage 1 and 2 landfill sources of leachate to this site, or the type of environment of this site, being a catchment drain leading to a sump (as opposed to a leachate dewatering well).

  Apart from the seasonal trend in TRH at LMP02, there are no seasonal trends or long-term trends evident in the data for TRH, PAH, BTEX or phenols at any of the sites.

In summary, the Stage 3/4 landfill leachate sites record the highest contaminant concentrations (i.e. DW3, DW2 and TC Sump), in particular, DW3, which often records concentrations well above that of all the other sites. The preliminary data available for the Stage 5 landfill sites DW5 and DW6 indicate leachate here is of a similar quality to that of the Stage 3/4 landfill sites. The leachate pond sites LP01 and LP02 usually record contaminant concentrations lower than the Stage 3/4 and Stage 5 landfill sites, with LP02 recording higher concentrations than LP01. Where ANZECC (2000) trigger values are available usually record concentrations well above the trigger value. This is except for LMP02, which records dissolved metal concentrations below the respective trigger values. Contaminant concentrations at LMP02 are usually well below that of the other sites, although ammonia concentrations still remain well above the trigger value, and COD concentrations and the L/N ratio indicates this still is heavily impacted by leachate from the Stage 1 and 2 landfills.

As seen in the summary above, LMP02 has a strong seasonal pattern in contaminant concentrations, where concentrations typically increase over the course of the dry season, with the highest concentrations during the late dry season (September-December). Concentrations are usually lowest during the wet season (December to March). This is likely reflecting the changing relative proportions of surface water runoff to groundwater seepage reporting to this site, where:

- Fresh rainwater and runoff, which has had little contact time with the buried Stage 1 and Stage 2 landfill materials is lower in contaminants
- Infiltrated surface water and groundwater seepage that has had more contact with buried landfill materials has higher contaminant concentrations.

This was except for ferrous iron (II), which shows a seasonal pattern counter to this, indicating this parameter may be associated with surface water inputs and/or environmental conditions in the drain (i.e. the drain is excavated along the edge of the floodplain environment), and not reflective of leachate inputs.

Limitations

Of note in regard to the above summary, is that data for all leachate sites (except LMP02) is skewed towards the 2016/2017 monitoring period, given there is monthly data between July 2016 and April 2018, then no data until June 2019, then monthly data until March 2020. This is especially pronounced for the parameters that are only measured quarterly e.g. dissolved metals, nutrients, cations and anions, as these were only measured four times after sampling at these sites recommenced in June 2019. As such, the conclusions for these quarterly parameters could be said to represent mainly what was occurring at the site between July 2016 and April 2018. This includes any influences from how the landfills and the leachate were being managed at this time.

The above point is particularly important when considering the leachate pond (LP01 and LP02) data, where the southern leachate pond (LP02) generally has recorded higher concentrations compared to the northern leachate pond (LP01). LP01 also shows an increasing trend in contaminant concentrations (unrelated to seasons) between July 2016 and April 2018. This pattern is likely reflecting the specific operation of these ponds during the 2016/2017 period e.g. which pond was being filled, which was being drained, and which was being left un-used at the time.

Also, of note is that the data available for the Stage 5 landfill leachate sites DW5 and DW6 is very limited, with only a few sampling occasions since monitoring of these sites commenced in late 2019. As such, the characterisation of leachate directly sampled from the landfill dewatering points is skewed towards the Stage 3/4 landfill sites DW3, DW2 and TC Sump.

7.3 Surface water results

Direct sampling of surface water is undertaken for the monitoring program at five sites; as detailed above in Table 4-2 and shown in Figure 2-1
Figure 2-1. In summary, the sites comprise:

- 'GW Sump' representing surface runoff from the green waste processing and storage area. This site also likely receives surface runoff from the Stage 3 and Stage 5 landfills. Water overflows from this sump into the nearby bushland offsite.
- Site 'SW12' is a catchment dam at the base of the north-west corner of the Stage 3/4 landfill, and represents surface runoff from the northern and western sides of this part of the landfill, and also possibly seepage from the within the Stage 3/4 landfill. Water from this catchment dam overflows into the offsite downstream environment following heavy rainfall, or is also often pumped out into the leachate reticulation system.
- Wash-down water from large commercial waste transport vehicles on exiting the SBWMF is represented by the site 'Wheel Wash'. Water sampled from the wheel wash sump has prior passed through an oily water separator. Water from this sump is irrigated over the Stage 1 landfill area.
- Site 'STG1&2' represents surface runoff from central SBWMF areas, however it has only been possible to sample this site on two occasions, as it only flows during heavy rainfall. Water from this stormwater drain flows east offsite into the downstream wetland/floodplain environments.
- Monitoring of 'SW2' was initiated in 2015 in response to a seepage issue from the Stage 3/4 landfill. This issue has since been addressed and seepage at this location is no longer observed. Sampling of surface water site SW2 has only been possible once (i.e. November 2016) during the July 2016 to March 2020 monitoring period due to lack of water flow.

Given It has only been possible to sample site STG1&2 twice and SW2 once during the monitoring period, these sites have been excluded from the discussion below due to the small dataset and the inability to determine either seasonal or long-term trends through analysis. The following section concentrates on the SW12, Wheel Wash and GW Sump sites. In addition, a number of parameters (i.e. the majority of dissolved metals, nutrients, major cations and major anions) were only included in annual sampling of all the surface water sites and therefore have small datasets. Seasonal and long-term trend analysis has not been attempted for these annual parameters.

As per Section 4.6 above, assessment criteria for physical parameters and nutrients e.g. pH, total nitrogen (TN), nitrate+nitrite (NOx), total phosphorus (TP) and filterable reactive phosphorus (FRP), are taken from the *Water Quality Objectives (WQOs) for the Darwin Harbour Region – Background Document* (NRETAS 2010) for the 'Upper Estuary'. ANZECC (2000) trigger values for 90% species protection in aquatic ecosystem (marine) have been used for toxicant parameters (i.e. dissolved metals, ammonia, PAHs etc.).

7.3.1 Physical parameters

Table 7-6 below provides the median physical parameter concentrations calculated for each site, based on all available data collected from July 2016 to March 2020. Individual parameters are further discussed below.

pH:

Median pH values for the three surface water sites are close to neutral and range from pH 6.67 at Wheel Wash to pH 7.47 at SW12.

Over the July 2016 to March 2020 monitoring period, surface water pH's predominantly remained within the WQO range of 6.0 to 8.5, with all three sites showing evidence of an increasing pH trend (i.e. more alkaline).

Increasing seasonal trends were identified at all three sites. The pH at all sites gradually rising during the

dry season, with the highest concentrations typically occurring during the late dry season (September), and lowest during the wet season (December to March). This trend is not at evident during the 2018/19 wet season, due to a drier than average wet season.

EC:

The Stage 3/4 catchment dam site, SW12, recorded the highest median EC of 2,284 µS/cm, followed by GW Sump with an EC of 839 µS/cm, and then Wheel Wash with an EC of 512 µS/cm. There is no WQO for EC, therefore results have not been assessed against a trigger value.

Over the July 2016 to March 2020 monitoring period, EC concentrations measured at each surface water site were variable from month to month, and none of the sites showed clear evidence of a long-term increasing or decreasing trend.

Wheel Wash is the only site with a clear seasonal trend in EC concentrations. Similarly, to pH, the EC at this site gradually increases during the dry season, with the highest concentrations typically occurring during the late dry season (September), and lowest during the wet season (December to March). This is likely due to the evapo-concentration of chemical constituents in the sump due to the increased rate of evaporation during the dry season and decreased requirement to pump-out the sump and irrigate over the Stage 1 landfill area.

DO:

Median DO concentrations for the surface water sites range between 9 and 55% saturation. This is relatively low for surface water bodies and is indicating a high oxygen demand possibly due to contaminants in the surface water and/or reflecting the fact that these are not flowing surface water bodies but are usually stagnating water contained within a pit/sump or dam.

Table 7-6. Surface water site median physical parameter concentrations calculated for all data collected July 2016 – March 2019.

Parameter	Units	SW12	Wheel Wash	GW Sump
pH	pH units	7.47	6.67	7.33
EC	µS/cm	2,284	512	839
DO	%sat	55	9	28
Temp	°C	29.0	30.3	30.2

7.3.2 Dissolved metals

Sampling of dissolved metals for the surface water sites occurred as part of the annual sample analysis suite, therefore seasonal trend analysis is not possible. The following discussion outlines the range of the results for the dissolved metals and comparison to the ANZECC (2000) trigger values. Iron (II) and (III), cadmium and nickel have been excluded from the discussion due to concentrations being below the LOR, or due to a lack of trigger values for comparison.

Chromium:

Chromium (VI) concentrations for all sites (where the LOR was 0.01 mg/L) were below the ANZECC (2000) trigger value, whereas chromium (III) concentration were at times, above the LOR and therefore above the trigger value of 0.049 mg/L.

Chromium concentrations do not appear to be increasing or decreasing over the long-term, at any of the surface water sites, based on the available data.

Copper:

Prior to February 2020, annual copper concentrations ranged from 0.001 to 0.005 mg/L, with no particular increasing or decreasing trend. Site SW12 was the only site to exceed the ANZECC (2000) trigger value of

0.003 mg/L, with a concentration of 0.005 mg/L on one occasion.

During the February 2020 annual sampling, all three sites were above the ANZECC (2000) trigger value. Sites SW12 and Wheel Wash were seven and nine times higher than the trigger value respectively. Wheel Wash water has variable water quality, which is likely due to the variance of vehicles and equipment being cleaned at the site.

SW12 is located at the north-west of Stage 3/4, and the elevated copper concentrations, are potentially indicating leachate impacts; either from the seepage of leachate from the landfill, or from surface water runoff flowing off the landfill that has picked up residues from the irrigation of leachate back onto the landfill.

Manganese:

Median manganese concentrations range from 0.07 mg/L at site GW Sump to 0.30 mg/L at site Wheel Wash. Manganese concentrations at the Wheel Wash site consistently exceed the ANZECC (2000) trigger value of 0.08 mg/L.

Similarly, to the copper concentrations, all three sites saw an increase in concentrations during the February 2020 annual monitoring event. Sites SW12 and Wheel Wash were 1.3 times and 5 times higher than the trigger value, respectively.

Lead:

Median lead concentrations ranged from below the LOR (<0.001 mg/L) to 0.003 mg/L between 2017 and 2019, with no particular increasing or decreasing trends across sites and no exceedances of the ANZECC (2000) trigger value of 0.0066 mg/L.

During the annual sampling event for 2020, sites SW12 and Wheel Wash recorded the highest lead concentrations since sampling began in 2016. Whilst site SW12 was under the ANZECC (2000) trigger value, the Wheel Wash site recorded a concentration almost four times higher than the trigger value. The GW Sump site recorded the lowest concentrations since sampling began (i.e. below the LOR). The monitoring results appear to be spikes in the data and no long-term increasing or decreasing trends in lead concentrations can be determined.

Zinc:

Median zinc concentrations ranged from below the LOR (<0.05 mg/L) to 0.087 mg/L between 2017 and 2019, with the Wheel Wash site recording an exceedance of the ANZECC (2000) trigger value of 0.023 mg/L on one occasion.

Similarly, to the other dissolved metals discussed above, the 2020 annual sampling event recorded exceedances of the trigger value at SW12 and Wheel Wash. There have been no exceedances of the zinc trigger value for the GW Sump site.

7.3.3 Nutrients, organic content and oxygen demand

Table 7-7 provides the median nutrient and organic content concentrations calculated for each site, based on all available data collected between July 2016 and March 2020. Individual parameters are further discussed below.

Ammonium (NH_4):

The surface water samples are analysed for total ammonia as nitrogen (denoted as NH_3-N) annually, and ammonium (NH_4^+ as N), monthly. See Section 7.1.3 of this report for an explanation as to the relationship of ammonia and its chemical species. Given the larger range of data available, NH_4 is discussed with a comparison to the annual ammonia concentrations to determine the approximate percentage of NH_4^+ within NH_3-N.

Analysis of the NH_4^+ ion, identified that it was present in 95%, 98% and 97% of the ammonia concentrations at sites SW12, Wheel Wash and GW Sump, respectively. Therefore, the ANZECC (2000) trigger value

concentration of 1.2 mg/L can be applied to the NH_4 results.

The Wheel Wash site recorded NH_4 concentrations above the trigger value for 97% of the sampling events, with the highest concentration observed being 37.1 mg/L. SW12 recorded concentrations about the trigger value for 55% of the sampling events, and GW Sump site recorded concentrations above the trigger value for 30% of the sampling events.

Ammonium concentrations do not appear to be increasing or decreasing over the long-term.

Total organic carbon (TOC):

Wheel Wash recorded the highest median TOC concentration of 55.0 mg/L, followed by GW Sump with a concentration of 45.5 mg/L and then SW12 with a concentration of 37.0 mg/L. The quality of water within the Wheel Wash site is directly related to the variability of vehicles and machine that use the facility. The Wheel Wash site was the only site to have a general seasonal trend, with the highest TOC concentrations occurring towards the start of the dry season and the lowest in the wet season. Similarly, to EC, this is likely due to the evapo-concentration of chemical constituents in the sump due to the increased rate of evaporation during the dry season and decreased requirement to pump-out the sump and irrigate over the Stage 1 landfill area.

TOC concentrations do not appear to be increasing or decreasing over the long-term.

Chemical oxygen demand (COD):

ANZECC (2000) does not specify guideline values for COD given this is not strictly a toxicant, although high concentrations can indicate high inputs of organic matter to waterways, and can lead to eutrophication.

COD is consistently highest at the Wheel Wash site, recording a median concentration of 253 mg/L, compared to GW Sump with a median concentration of 228 mg/L, and SW12 with a median concentration of 110 mg/L.

COD concentrations do not appear to be increasing or decreasing over the long-term at any of the surface water sites.

Alkalinity:

ANZECC (2000) does not specify guideline values for alkalinity given this is not strictly a toxicant, rather a parameter which aids in the determination of acid-neutralising capacity of the water system.

Alkalinity is consistently highest at the GW Sump site, recording a median concentration of 173 mg/L, compared to Wheel Wash, which has a median concentration of 143.5 mg/L, and SW12 which has a median concentration of 130.5 mg/L.

Alkalinity concentrations do not appear to be increasing or decreasing over the long-term at any of the surface water sites.

Table 7-7. Surface water site median nutrients, organic content and oxygen demand concentrations calculated for all data collected July 2016 – March 2019.

Parameter	Units	SW12	Wheel Wash	GW Sump
Ammonium	mg/L	1.70	7.21	2.03
TOC	mg/L	37	55	45.50
COD	mg/L	110	235	228
Alkalinity	mg/L	130.50	143.50	173

7.3.4 Hydrocarbons and other miscellaneous parameters

Hydrocarbon concentrations (i.e. total petroleum hydrocarbons, polycyclic aromatic hydrocarbons and total phenolics) and other parameters such as RDX and TNT, for all sites had concentrations below the LOR.

Refer to the SBWMF water monitoring database for further information regarding the LOR limits and concentration results.

7.4 Summary of surface water results

There are elevated concentrations of surface water parameters across the SBWMF, which appear to be influenced by their location at the site and their proximity to specific operational areas of the landfill.

There do not appear to be any long-term increasing or decreasing trends in surface water quality parameters for the 2016 – 2020 dataset. However, a spike in surface water data was observed in February 2020 with several metals exceeding the ANZECC (2000) trigger values at the SW12 and Wheel Wash sites, in concentrations higher than during previous annual monitoring events. This was particularly the case for copper, lead and zinc concentrations. The cause of this spike cannot be determined based on the scant data i.e. only annual. If metals were analysed monthly at these sites during the wet season, it may be evident that concentrations similar to those measured during February 2020 occur more frequently and have also occurred in the past, however no seasonal trends can be determined from the dataset.

Some seasonal trends were observed for surface water parameters, which are expected given the nature of wet season dilution/mobilisation of certain parameters, and dry season concentration of certain parameters.

A summary of key findings identified in the above analysis for the three surface water sites is provided in Table 7-8.

Table 7-8. Summary of key findings for surface water sites.

Monitoring sites	Summary of observations	Justification/Inference
SW12	Surface waters tend to have high EC in comparison to WQOs and in comparison, to other sites. Copper, zinc and NH_4 concentrations have exceeded their respective ANZECC (2000) trigger values.	When a seasonal trend was identified, concentrations of contaminants were higher during the wet season, when runoff was occurring from Stages 3/4. SW12 is known to overflow during the wet season to the receiving environment (bushland located to the west and north-west of the site.
Wheel Wash	EC concentrates during the dry season and displays a seasonal trend. The copper concentration recorded during the 2020 monitoring event was higher than previous recorded concentrations and was nine times the ANZECC (2000) trigger value. Manganese, lead, zinc, NH_4 and concentrations have exceeded their respective trigger values. TOC and COD concentrations are higher at Wheel Wash compared to other surface water sites. Spikes in data have been observed, however no consistent seasonal trends have been observed with the exception of EV values.	The variability of vehicles and equipment cleaned at the site is introducing a number of physical and chemical compounds to the water. Seasonal trend in increased EC during the dry season is a result of concentration as evaporation rates are higher. Water from the Wheel Wash is irrigated across Stage 1.
GW Sump	NH_4 concentrations exceeded the ANZECC (2000) trigger values on 30% of monitoring events, which is less than SW12 and Wheel Wash sites. TOC and COD were similar to Wheel	The site is close to the green waste section of SBWMF, which account for the high TOC and COD concentrations in comparison to SW12. GW Sump is known to overflow during the wet season to the receiving environment (i.e. bushland to the west of site).

	Wash, and therefore higher than SW12. Seasonal trends were easily attainable for this site. There was no indication of long-term increasing or decreasing concentrations.	

7.5 Groundwater results

Groundwater monitoring during the July 2016 to March 2020 monitoring period involved the sampling of over 40 bores on a predominantly monthly basis. This network of groundwater monitoring bores installed across the SBWMF is described in detail in Section 4.3.1 above and locations shown in Figure 2-1 Figure 2-1. Even taking out bores which were dry periodically, this has equated to more than 730 samples, with each of these samples analysed for more than 30 parameters. As such, presenting and describing this dataset in a succinct way that highlights the key issues and trends is difficult. Given this, only the key median concentrations are included in the discussion below and key trends presented in the graphs in Appendix B. For further detail regarding the data used to derive the interpretations below, please refer to the SBWMF water quality monitoring database.

7.5.1 Physical parameters

pH:

pH in groundwater across the site predominantly remains within the range of 4 to 7 i.e. acidic to neutral. This pH range is typical of the lateritic surface groundwater aquifers in the Darwin region. Three bores however, consistently record extremely alkaline pH's well above this range: GW1-12, (median pH of 11.86), GW4-12 (median pH of 11.12) and GW15-12 (median pH of 9.01). These alkaline pH values cannot be explained by any natural aquifer features or even the ingress of leachate. It is suspected that these bores are contaminated with the cement grout used to seal the annulus of the bores (between the screened interval and surface) after they were installed.

In regards to the other non-cement impacted bores, with median pHs between 4 and 7, two of these bores record relatively acidic median pH values: GW3-3 located to the east of the leachate storage ponds, and WW1 located on the eastern edge of Stage 3/4, which recorded a pH median value of less than 4. This is likely reflecting the pH of the surface water runoff directly infiltrating into the groundwater at these locations, with the acidity derived from the acidic nature of rainwater in the Darwin region.

A further 29 bores record mildly acidic median pH values (between 4 and 6). These are located across the entire site and include all three deep bores drilled to 30 m, as well as shallow (3 m) and mid-depth (12 m) bores.

The remaining six bores record close to neutral median pH's i.e. between 6 and 7: GW3-12, GW5-3, GW5-12, GW7-12, GW8-3 and GW12-3. All these bores are located on the eastern boundary of the site, with the exception of GW12-3, which is located on the western boundary.

EC:

The range in EC concentrations measured in bores across the site is extreme; with median concentrations ranging from very fresh (31.1 µS/cm) to hypersaline (78,024 µS/cm, which is higher than the salinity of seawater). Two sites with the highest EC values are GW8-12 (median 78,024 µS/cm) located to the south-east of the site adjacent to the Principal Depot, and WW6 (median 68,246 µS/cm), located at the north-west corner of the Stage 3/4 landfill, i.e. on opposing sides of the site. These EC's are extremely high considering the highest median EC for leachate is 25,051 µS/cm. Potentially the cause of these extreme EC's is a combination of seawater intrusion and leachate impacts.

Bores recording median EC values above 10,000 µS/cm comprise GW1-12 and GW7-12, located on the eastern boundary, GW14-12 located on the north-western boundary and to the west of Stage 4, and WW13 located on the northern boundary and adjacent to the leachate storage ponds. Saltwater intrusion from tidal influence to the north of the site may be influencing some of these bores.

GW6-30, located within the middle of the site, and screened within the deeper sandstone aquifer below 20 m, recorded the lowest median EC value of 31.1 µS/cm. Bores towards the southern boundary of the site GW9-12, GW10-3 and GW10-12, GW11-3 and GW11-12, were also relatively fresh; all recording median EC

values below 140 µS/cm.

DO:

DO median concentrations were almost always less than 50% saturation, with the median ranging between 6.8 and 66.7% saturation. Low DO is expected in groundwater given it has been out of contact with oxygen in the atmosphere for a period of time.

7.5.2 Dissolved metals

Sampling of dissolved metals for the groundwater sites occurred as part of the quarterly and annual monitoring rounds. The following discussion outlines the range of results and comparison to the ANZECC (2000) guidelines. Median values that predominantly record concentrations below the limit of reporting (i.e. iron (Fe(II) and Fe(III) chromium (Cr(III) and Cr(VI)) are not discussed in further detail. In general, seasonal trends were not able to be determined, with the exception of WW6 and GW8-12.

Cadmium:

Cadmium median concentrations ranged between 0.0001 mg/L and 0.0157 mg/L. Most of the bores record median cadmium concentrations below the LOR (i.e. <0.001 mg/L). Three bores however, record elevated dissolved cadmium. WW6 recorded the highest median concentration of 0.0157 mg/L, which is above the ANZECC (2000) trigger value of 0.014 mg/L. This was followed by GW8-12 and WW13, with median concentrations of 0.0044 mg/L and 0.0016 mg/L respectively. Significantly, these concentrations are higher than those recorded in the leachate (see Section 7.1.2 above). The leachate recorded dissolved cadmium concentrations mainly below the LOR (<0.001 mg/L), however it is suspected that cadmium is in fact present in the leachate, it is just bound to the suspended and organic material and not in the dissolved form. When leachate enters the more acidic groundwater environment, with lower TOC concentrations, potentially the cadmium becomes more soluble.

Clear seasonal trends were evident at both sites WW6 and GW8-12, with increased cadmium concentrations observed mid-wet season and decreased concentrations around the mid-dry season. No evidence of long-term increasing or decreasing trends were evident.

Manganese:

Manganese median concentrations ranged between 0.001 mg/L and 53.9 mg/L. The site with the highest median manganese concentration, above the ANZECC (2000) trigger value of 0.08 mg/L, was WW6, with a concentration of 53.90 mg/L. The historic manganese concentrations for WW6 range from 49.9 mg/L to 61.4 mg/L, which is significantly higher than all other monitoring sites. Similarly, to cadmium, these manganese concentrations are several times higher than what is recorded in the leachate. Potentially, insoluble manganese contained within the leachate also becomes more soluble in the acidic, lower TOC groundwater environment.

GW14-12 recorded the next highest median manganese concentration of 3.44 mg/L. Other sites that recorded results above the trigger value were GW7-3, GW7-12, WW7 and WW9.

A clear seasonal trend was observed at WW6, with increased manganese concentrations observed mid-wet season and decreased concentrations around the mid-dry season. No long-term increasing or decreasing trends were observed.

Copper:

Median copper concentrations ranged between 0.001 mg/L and 0.061 mg/L. WW6 and GW8-12 recorded the highest median concentrations across groundwater bores of 0.061 mg/L and 0.045 mg/L respectively. These results were above the ANZECC (2000) trigger value concentration of 0.003 mg/L. The highest copper concentrations at these bores were observed during the January 2020 monitoring round.

Copper concentrations were recorded above the LOR at the majority of bores during the July 2016 to March 2020 monitoring period, with 60% of the 40 bores recording median values above the trigger value, with the

exception of GW4-30 and GW5-12, which consistently record copper concentrations below the LOR.

Clear seasonal trends were not observed at any of the groundwater bores, nor were any long-term increasing or decreasing trends.

Nickel:

Median nickel concentrations ranged between 0.001 mg/L and 1.25 mg/L. The site with the highest median nickel concentration, above the ANZECC (2000) trigger value of 0.2 mg/L was WW6, with a concentration of 1.25 mg/L. Nickel concentrations at WW6 are consistently above the trigger value, with concentrations increasing during the wet season and decreasing during the dry. Median nickel concentrations for all other bores were below the trigger value, however concentrations are predominantly above the LOR.

Seasonal or long-term increasing or decreasing trends were not observed for any other monitoring bores.

Lead

Median lead concentrations ranged between 0.001 mg/L to 0.013 mg/L. WW6 has recorded the highest median lead concentration, which exceeds the trigger value of 0.0066 mg/L. The median lead concentration for WW13 (0.008 mg/L) also exceeds the trigger value.

Most of the remaining bores reported concentrations consistently below the LOR. Seasonal trends were not identified, nor were any long-term increasing or decreasing trends.

Zinc

Median zinc concentrations ranged between 0.005 mg/L to 2.64 mg/L. The site with the highest median nickel concentration was WW6, with a concentration of 2.64 mg/L, almost 115 times above the ANZECC (2000) trigger value of 0.023 mg/L.

The majority (i.e. 80%) of groundwater bores recorded median zinc concentrations that exceeded the trigger value. Bores that did not exceed the trigger value include GW1-12, GW3-3, GW4-12, GW10-12, GW11-3, GW12-3, GW12-12 and GW15-3.

Seasonal or long-term increasing or decreasing trends were not observed for any monitoring bores.

7.5.3 Nutrients, organic content and oxygen demand

Ammonia (NH_3) and Ammonium (NH_4):

The un-ionised species of ammonia can be harmful to aquatic organisms whilst the ionised ammonium is relatively harmless. As NH_3 is considered a toxicant, the ANZECC (2000) guidelines have adopted a trigger value 1.2 mg/L, whereas there is no guideline value for NH_4.

NH_3 is frequently detected in all of the groundwater bores on-site, however over the review period it has only been detected at concentrations above the guideline value in GW7-3, GW8-3, GW8-12, GW13-12 and WW6. Within these bores, NH_3 was detected at median concentrations ranging from 1.37 mg/L (WW6) to 3.70 mg/L (GW7-3).

As previously discussed, there is a relationship between the proportion of NH_3 and NH_4 in any given sample, which is driven by pH and temperature. However, the database does not always include NH_3 concentrations for the same monitoring rounds as NH_4 concentrations, making it difficult to infer any relationship. Overall, the bores impacted by NH_3 concentrations above the trigger value were also found to have similar median concentrations of NH_4, with the exception of GW8-3. The median concentration of NH_3 detected in GW8-3 was 3.66 mg/L, whilst NH_4 was 7.56 mg/L.

Nitrate (NO_3):

There is no trigger value for nitrate. Nitrate was detected frequently in all of the groundwater bores however in the majority of bores it was at median concentrations of less than 1 mg/L. Bores GW2-3, GW5-3, GW6-12, GW7-3, GW8-3, GW14-3, WW1, WW3, WW5, WW7 and WW10 all have median nitrate concentrations

above 1 mg/L, with concentrations ranging from 1.05 mg/L (WW10) to 14.5 mg/L (WW1).

Total organic nitrogen (TON):

There is no guideline value for TON. TON was detected frequently in all of the groundwater bores however in the majority of bores it was at median concentrations of less than 1 mg/L. Bores GW7-3, GW8-3, GW12-3, WW1, and WW7 all have median TON concentrations ranging from 1.3 mg/L (WW7) to 2.6 mg/L (WW1).

Filterable reactive phosphorus (FRP):

Results for FRP have only been provided from December 2017 to March 2019. Based on this dataset, FRP was only frequently detected above the LOR in GW2-12, GW4-30, GW5-12, GW7-12, GW12-3, WW1, WW6 and WW7. Where concentrations of FRP were detected, the median concentration was found to be above the trigger value of 0.05 mg/L in GW5-12 (0.05 mg/L), GW12-3 (0.09 mg/L), WW1 (0.17 mg/L) and WW6 (0.12 mg/L).

Total organic carbon (TOC):

There is no trigger value for TOC. TOC was detected at concentrations above the LOR in approximately 50% of the groundwater bores. Where TOC concentrations were recorded, it was at concentrations of less than 2 mg/L in all bores with exception to GW6-3, GW7-3, GW8-3, GW12-3, GW13-12, GW14-3 and WW7. Within these bores, the concentration of TOC ranged from 4 mg/L (GW6-3 & GW13-12) to 23 mg/L (GW12-3).

Chemical oxygen demand (COD):

The median concentrations of COD recorded were variable across all bores ranging from 5 mg/L to over 200 mg/L, with the highest concentration recorded at WW6 (206.5 mg/L). WW6 recorded the highest COD concentration observed throughout the monitoring program of 7,000 mg/L in July 2016.

7.5.4 Anions, cations and L/N ratio

Sodium:

There is no trigger value for sodium. Median sodium concentrations ranged between 2 mg/L and 16,500 mg/L, with the highest median concentrations recorded at GW8-12 (16,500 mg/L) and WW6 (13,600 mg/L).

Sodium was observed to be consistently high at GW2-12, GW7-12, GW14-12, WW5 and WW13, ranging from 1,410 mg/L at WW5 to 3,570 mg/L at GW2-12.

Potassium:

There is no trigger value for potassium. Median potassium concentrations ranged between 1 mg/L and 377 mg/L, with the highest median concentrations recorded at GW8-12 (377 mg/L), and WW6 (233 mg/L).

Potassium was observed to be consistently high at GW2-12, 4-12, 7-3, 7-12, 8-3, 8-12, 12-3, 14-12 and WW6, ranging from 32 mg/L at GW2-12 to 377 mg/L at GW8-12.

Calcium:

There is no trigger value for calcium. Median calcium concentrations ranged between 1 mg/L and 1,460 mg/L, with the highest median concentrations recorded at WW6, and GW8-12 (1,060 mg/L).

Calcium was observed to be consistently high at GW2-12, GW4-12, GW7-3, GW7-12, GW8-3, GW8-12, GW12-3, GW14-12 and WW6.

Magnesium:

There is no guideline value for magnesium. Median magnesium concentrations ranged between 0.6 mg/L and 2080 mg/, with the highest median concentrations recorded at GW8-12 (2,080 mg/L), and WW6 (1,840 mg/L).

Magnesium was observed to be consistently high at GW2-12, 7-12, 8-12, 14-12 WW5, WW6 and WW13, ranging from 124 mg/L at GW7-12 to 2,080 mg/L at GW8-12.

Sulfate:
There is no trigger value for sulfate. Median sulfate concentrations ranged between 1 mg/L and 3625 mg/L, with the highest median concentrations recorded at GW8-12 (3,625 mg/L), and WW6 (3,025 mg/L).

Sulfate was observed to be consistently high at GW2-12, GW7-12, GW8-12, GW14-12 WW5, WW6, WW7 and WW13, ranging from 222 mg/L at WW7 to 3,625 mg/L at GW8-12.

Alkalinity:
There is no trigger value for alkalinity. Median alkalinity concentrations ranged between 1 mg/L and 909 mg/L, with the highest median concentrations recorded at GW1-12 (909 mg/L), and GW8-3 and GW8-12 with median alkalinity concentrations of 276 mg/L and 273 mg/L, respectively.

Alkalinity was observed to be consistently high at GW1-12, GW7-12, GW8-3, GW8-12, GW12-3, GW14-12, WW5, WW6, WW7 and WW13, ranging from 124 mg/L at GW7-12 to 909 mg/L GW1-12.

Chloride:
There is no trigger value for chloride. Median chloride concentrations ranged between 4 mg/L and 29, 550 mg/L, with the highest median concentrations recorded at GW8-12, and WW6 with a median concentration of (25,900 mg/L), in comparison the next highest median concentration was at GW2-12 (6,980 mg/L).

Chloride was observed to be consistently high at GW2-12, GW7-12, GW8-12, GW14-12, WW5, WW6 and WW13.

L/N ratios:

L/N ratios, calculated within the SBWMF database identified that the following bores, consistently exceeded the L/N ration of 10:

- GW6, GW12 and GW13, nested bores at all depths.
- GW7, GW8, GW10 and GW11 in the shallow bores (3 m)
- GW9-12 (singular bore).

Given Bores GW9-12, GW10-3 and GW11-3 are up-gradient of the site and not subject to any leachate impacts, the validity of this L/N ratio is questionable.

7.5.5 PFAS

Several PFAS substances were detected above limits of reporting, predominantly at GW8-3 and GW13-12.

PFOS was detected above the LOR at sites GW7-12, GW8-3, GW11-12, GW12-12 and GW13-12. GW8-3 recorded PFOS above the PFAS NEMP recreational water guidance value (0.07 µg/L) during both instances where it was sampled (i.e. concentrations of 0.32 µg/L and 0.47 µg/L).

7.5.6 Hydrocarbons

Hydrocarbon concentrations (i.e. total petroleum hydrocarbons, polycyclic aromatic hydrocarbons) for all sites had concentrations below the LOR. Refer to the SBWMF water monitoring database for further information regarding the LOR limits and concentration results.

7.6 Summary of groundwater results

There are elevated concentrations of groundwater parameters across the SBWMF, which appear to be influenced by their location at the site and their proximity to specific operational areas of the landfill, as well as the specific aquifer depth.

In particular, six out of the 40 existing groundwater monitoring bores have recorded consistently high levels of various parameters. These are GW2-12, located to the north-east of the leachate ponds, G8-12 located to

the east of the Stage 1 landfill, GW14-3, GW14-12, WW6 and WW7 located to the north-west of the Stage 3/4 landfill, and WW13 located on the northern site bound and to the south-west of the leachate ponds. A summary of key findings identified in the above analysis for these six groundwater bores is provided in Table 7-9.

Bores WW6 and GW8-12 recoded consistently elevated concentrations of various parameters in comparison to other monitoring bores, with several exceedances of guideline trigger values. These bores are located at different area within SBWMF, however they are both in close proximity to landfills, i.e. WW6 located to the north-west of the Stage 3/4 landfill and GW8-12 located on the eastern site boundary adjacent to the Stage 1 landfill.

Bore WW6 is a deep bore at 20.4 m and is in close proximity to WW7 and the nested GW14, which are 12 m or less in depth. Both WW7 and GW14 recorded several elevated parameter concentrations in comparison to other bores located across SBWMF, however not to the extent of WW6.

There were some observable seasonal trends for EC and certain metals at WW6 and GW8-12 with concentrations increasing in the mid-wet season and reducing in the dry season. There do not appear to be any long-term increasing or decreasing trends in groundwater quality parameters for the 2016 – 2020 dataset.

There is currently no offsite upstream groundwater quality data available for use as a comparison of background water quality, however bores GW10 (3 and 12 m), GW11 (3 and 12 m) and GW9-12 are located on the southern boundary of SBWMF and correlate with the high groundwater levels identified in Figure 6-2.

Groundwater in these bores is of consistently good quality compared to the majority of bores within SBWMF, with low EC and below trigger value zinc concentrations. However, GW9-12, GW10-3 and GW11-3 consistently exceed the L/N ratio of 10, which is recommended for removal from the future monitoring program (see Section 9.1). Additionally, GW11-3 was one of five bores to record PFOS concentrations above the limit of detection.

Table 7-9. Summary of key groundwater sites

Monitoring sites	Summary of observations	Justification/Inference
GW2	GW2-12 recorded high levels of some dissolved metals, in particular zinc. High levels of anion and cation concentrations were also observed; however, L/N ratios are below 10.	The higher concentrations of anions and cations indicate that there is likely saline intrusion, due to GW2-12 position, north of the SBWMF. The GW2 bores are located on the boundary of SBWMF with bushland to the north and east.
GW8	GW8-12 recorded high levels of some dissolved metals i.e. cadmium, copper (above ANZECC (2000) trigger value) and zinc. EC values are highly saline and ammonia concentrations are above trigger values. High levels of anions and cations were common. L/N ratios commonly exceed 10.	Leachate ingress is likely in this area of SBWMF, due to GW8's positioning, east of the unlined Stage 1 landfill and south of leachate site LMP02. The GW8 bores are located on the boundary of SBWMF with bushland to the east.
WW6, WW7, GW14	WW6 recorded several exceedances of trigger values for cadmium, nickel, lead, zinc and ammonia. WW6 also had higher COD than all other bores and highly saline EC values. WW7 and GW14 had high EC and anion and cations including sodium, manganese, calcium, sulfate and alkalinity.	This cluster of monitoring bores is located on the north-western boundary of SBWMF and the Stage 3/4 landfill. Leachate activity and ingress is likely in this particular area due to the exceedance in ANZECC (2000) guidelines, high COD and ammonia. As surface and groundwater flows during the wet season flow towards the north-west (see Figure 6-2), the receiving environment (undisturbed bushland located to the west and north-west of the site) is of importance.

WW13	WW13 recorded high EC, cadmium and lead, as well as some cations and anions (sodium, magnesium, sulfate, alkalinity and chloride).	WW13 is located on the northern boundary of the site and to the immediate south-west of the lined leachate treatment ponds. It is unlikely that the leachate treatment ponds are influencing WW13. Groundwater contours identified in Figure 6-2 indicate WW13 may be influenced by the Stage 3 landfill. The receiving environment to the north is undisturbed bushland.

8 GROUNDWATER AND SURFACE WATER IMPACTS

Leachate is generated throughout the SBWMF and is of a quality that is indicative of an active landfill site. This leachate has the potential to impact on surface and groundwater quality within the SBWMF and in the receiving environment.

The SBWMF is located on a low-lying peninsula with tributaries from the Leanyer Swamp located on the western and eastern boundaries of the site. Hydrogeological modelling detailed in Section 6 indicates that groundwater's flow in an eastern and norther-eastern, and western direction across the site and towards the Leanyer Swamp tributaries and surrounding bushland i.e. the receiving environment (see Figure 6-2). Surface water mimics this general flow direction, from the southern extent of the site to the north-east and north-west towards Leanyer Swamp, as well as being directed across the site to its boundaries through drainage resulting from site infrastructure.

The high ammonia, TOC, COD and BOD found in the leachate have the potential to lead to eutrophication of waterways downstream. Additionally, the high metals, ammonia, hydrocarbons and PFAS in leachate can be toxic to aquatic organisms downstream.

Leachate is produced through landfilling activities and the decomposition and degradation of waste. Leachate is captured in sumps across the site and then managed according to the specific area of the SBWMF including:

- Stage 1/2: Intercepted leachate is pumped to a surface irrigation system operated within the plateau area of Stage 1. This area is unlined.
- Stages 3 to 6: Leachate from each sump is pumped through a rising main to two 15 ML covered leachate storage ponds (Northern Pond and Southern Pond). These ponds are lined and contain a leachate detection system.
- Stage 3/4: Leachate from the storage ponds is pumped to a surface irrigation system operated within the plateau are of Stage 3/4, which is lined.

The location of these landfills correlates with the surface and groundwater flow directions (i.e. Stage 1 and 2 landfills correlate with the eastern and north-eastern flow direction, and Stage 3 and 4 landfills correlate with the western flow direction, see Figure 6-3). A number of surface and groundwater monitoring sites are located down gradient of these landfills to provide an indication of impacts to water quality as a result of leachate generation. These landfills, their corresponding flow directions and monitoring locations are discussed in the following sections.

8.1 Stage 1 and 2 landfills

Surface and groundwater flows along the eastern and north-eastern boundary of the site (see Figure 6-2). These offsite directional flows correlate with the location of the Stage 1/2 landfills, which are unlined. Leachate is intercepted through a sub-surface toe drain, collected in a sump and irrigated across the Stage 1 plateau. The nested groundwater bores GW4, GW5, GW7 and GW8 are considered down gradient of this area based on the hydrogeological modelling and are along the eastern boundary of the site. The leachate monitoring site LMP02 is to the east of the Stage 1 landfill and there are no surface water sites downstream of the Stage 1/2 landfills or along the eastern site boundary.

LMP02 is a leachate collection sump however it also receives surface water runoff that has not come in contact with landfill wastes, and therefore generally has the lowest contaminant concentrations off all the leachate monitoring sites. Water at LMP02 therefore has a seasonal pattern for several analytes, where concentrations are high during the dry season and lower during the wet season (i.e. EC, metals, TOC, COD, BOD, chloride, alkalinity, potassium, sodium and TRH).

Dissolved metal concentrations recorded at LMP02 are usually below the relevant ANZECC (2000) trigger values, however ammonia concentrations consistently exceed the trigger values. PFAS concentrations in the Stage 1/2 landfills reflect older landfill signatures with the average PFOS+PFHxS concentration well above the PFAS NEMP recreational guideline, which pre-date the phasing out of these PFAS species for use in products.

Based on the results for LMP02, there is a possibility that some contaminants would be entering the receiving environment surface waters above trigger values and therefore at concentrations that could cause environmental harm.

Nested groundwater bores GW4 and GW5, which are located to the east of Stage 2 and to the north-east of Stage 2, had relatively good water quality with no exceedances of trigger values. These results indicate that groundwater down gradient of the Stage 2 landfill is not reflecting influences of leachate water at the nested GW4 and GW5 monitoring bores, which monitor water at 3 m and 12 m depths. There is no deep (30 m) bore located on the site boundary adjacent to the Stage 2 landfill, therefore impacts to depth cannot be determined.

GW7 located on the eastern boundary between the Stage 1 and 2 landfills recorded elevated analyte concentrations at particular depths. The shallow 3 m bore recorded manganese concentrations above the trigger value and elevated nutrient concentrations (ammonia, nitrate and TON), while the 12 m bore recorded elevated EC, cations and anions. The groundwater quality at GW7 represents similar concentrations to the LMP02 leachate water.

The GW8 nested bore recorded some of the highest concentrations of analytes at SBWMF. GW8-12 in particular has very high EC (greater than seawater) and recorded dissolved metal (cadmium, copper and zinc) and ammonia concentrations above the trigger values, and consistently high anions and cations. While GW8-3 did not reflect these results, the concentrations at GW8-12 indicate seepage from the Stage 1 landfill which is unlined.

Whilst there are no surface water monitoring sites along the eastern site boundary, the Meckitt Creek floodplain is located to the east of SBWMF and surface and groundwater's will flow towards this system, however as no monitoring has occurred beyond the site boundary, it is not known if the receiving environments water quality is being effected.

8.2 Stage 3 and 4 landfills

Surface water and groundwater flows along the western site boundary, and are particularly isolated within the north-western corner of the site (see Figure 6-2). These offsite directional flows correlate with the location of the Stage 3/4 landfills, and positioning of groundwater monitoring sites WW6, WW7 and GW14. Leachate is monitored at DW2, DW3 and TC Sump for the Stage 3/4 landfills. Surface water is monitored at SW12 and SW2 which are both considered downstream of the Stage 3/4 landfills. Surface water from SW12 on the western site boundary of the Stage 3/4 landfills, is known to overflow during high rainfall events to bushland immediately west of the site.

Leachate contaminant concentrations are generally always highest at the Stage 3/4 landfill site DW3 for all leachate monitoring points. Groundwater bore WW5 and the surface water site SW2 are considered down gradient monitoring sites from DW3, however no data is available from SW2 due to sampling constraints and groundwater quality at WW5 is not reflective of the DW3 results.

Bores located down gradient of the Stage 3/4 landfills and adjacent to DW2 include WW6, WW7 and GW14, all of which indicate some water quality results influenced by leachate. WW7 and GW14 had high EC, manganese, nutrient, and anion and cation concentrations, with some analytes exceeding the trigger values. WW6 in particular recorded several exceedances of trigger values for cadmium, nickel, lead, zinc and ammonia. WW6 also had higher COD than all other bores across SBWMF and highly saline EC values (greater than seawater). WW6 is constructed to 20.4 m, which is deeper than the adjacent WW7 (5.8 m) and GW14 (3 m and 12 m) bores. Seepage from the Stage 3/4 landfills is entering this deeper aquifer and influencing water quality.

Despite the lining of the Stage 3/4 landfill, water quality data indicates that leachate migration is likely considering the topographic conditions, historic landfilling activities and location of the leachate collection points on the western boundary of the site. The Leanyer Swamp and Buffalo Creek are down gradient of flows from the western catchment of SBWMF, however as no monitoring has occurred beyond the site boundary, it is not known if the receiving environments water quality is being effected.

Improved leachate capture, particularly to control seepage to groundwater, as well as improved practices to reduce leachate runoff to surface waters is required to prevent impacts to the receiving environment.

9 MONITORING PROGRAM REVIEW

9.1 Review of parameters and analytes

Based on the above characterisation in Section 7, certain parameters and analytes are considered most useful in indicating impacts to water quality from SBWMF operations, whilst some analytes have been identified as unnecessary and therefore recommended for removal from the monitoring program. Table 9-1 provides a summary of the review of monitoring program parameters and analytes, and indicates those recommended for inclusion and removal in the program going forward.

It is proposed that the parameters listed in Table 9-1 for inclusion in future monitoring programs, be analysed consistently in all leachate, surface water and groundwater sampling for simplicity. The current arrangement of differing parameter suites that change depending on whether the site is leachate, surface water or groundwater, and also different between monthly, quarterly and annually is over complicated and leads to mistakes in sample preparation, sample submission to the laboratory and data entry. Having the same, consistent set of key parameters for all sampling at all times will also assist with streamlining data review and analysis.

Table 9-1. Monitoring program parameters and analyte review summary

Parameter / analyte	Review summary
Parameters and analytes recommended for inclusion in future monitoring programs	
Physical parameters (i.e. pH, temperature, EC and DO)	Very important for determining factors that can influence the behaviour of chemical constituents e.g. solubility.
Ammonia (NH_3 as N)	Concentrations are extremely elevated in landfill leachate, generally more than 1000x the ANZECC trigger value, and concentrations of this magnitude are unlikely to derive from natural sources.
Nitrate (NO_3), nitrite (NO_2) and nitrate+nitrite (NOx)	To date only NO_3 is included in the monitoring program, however review of the historic raw lab data, where both NO_2 and NO_3 are available shows NO_2 also makes up a significant proportion of the oxidised nitrogen in leachate. Only measuring and recording NO_3 in the database has meant a significant proportion of the oxidised nitrogen is not known. It is proposed that nitrite be added to the monitoring program.
COD	Concentrations are extremely high in the landfill leachate and concentrations of this magnitude are unlikely to derive from natural sources. BOD is generally correlated with COD, and it is not considered necessary to measure both.
Dissolved metals (chromium, copper, nickel, lead and zinc)	Concentrations are extremely high in the landfill leachate and concentrations of this magnitude are unlikely to derive from natural sources. Note that: cadmium (dissolved) is always very low in the leachate, but this is possibly because it is existing in the solid phase and/or sorbed to the suspended and organic matter. It is proposed that 'total' cadmium be measured as a trial in future monitoring rounds.
PFAS	Concentrations are high in the landfill leachate and it is only possible for PFAS to derive from un-natural sources. The particular PFAS species present can also be useful in determining the source of the contamination e.g. PFBS from Stage 3/4 landfill and PFOS from Stage 1 and 2 landfills.
TRH and BTEXN	Concentrations are relatively high in the landfill leachate, and it is unlikely these can derive from natural sources. Note that the individual TRH fractions and BTEXN compounds e.g. benzene, toluene etc need to be recorded in the database. The BTEX (sum) concentration has limited value and cannot be compared against the individual ANZECC (2000) guidelines for each of the individual BTEXN compounds. Note that naphthalene is included in the BTEXN suite. It was found that naphthalene was the only detectable PAH in

Parameter / analyte	Review summary
	the PAH suite, as such it is suggested that the PAH suite be taken out of the monitoring parameters provided naphthalene is still analysed.
Anions, cations and alkalinity	Important for determining factors that can influence the behaviour of contaminants.
Total phosphorus (TP)	Has not been included in the monitoring of leachate to date and very little filterable reactive phosphorus (FRP) data was collected during the monitoring period. It is proposed that TP be added to the leachate analysis suite, as this parameter is likely to be elevated and a potential contaminant of concern.
Analytes recommended for removal from future monitoring programs	
Chromium speciation analysis	Chromium (III) and chromium (VI) is of no value in leachate analysis as the matrix interferences mean that the laboratory LOR is raised well above the ANZECC (2000) trigger values. The sum chromium concentration is not affected by this and it is proposed this be analysed in future instead of chromium speciation.
Iron speciation analysis	The ferrous iron (II) and ferric iron (III) are of limited value in indicating leachate inputs to receiving waters.
RDX and TNT	Have always recorded levels below detection so are not useful as leachate impact indicators.
The L/N ratio	Is considered over-complicated, and also requires the derivation of extra parameters (e.g. NH_4^+), when the above-listed parameters would be sufficient for identifying leachate impacts. Also, in the groundwater results analysis below (see Section 7.5.4), L/N ratios greater than 10 were often recorded in bores which are up-gradient of the site and definitely not subject to any leachate impacts.

9.2 Review of sampling frequency

The current monitoring program sampling frequency is provided in Table 4-3. As a result of this data review, a more targeted sampling frequency is proposed and presented in Table 9-2.

Table 9-2. Monitoring program sampling frequency review summary

Month	Groundwater		Surface Water	Leachate	Standard suite
	Levels	Chemical parameters			
January	X	X	X	X	**Field parameters:** SWL, pH, EC, DO, temperature **Lab parameters:** • Major ions, NH_4, TDS, COD, TOC • Major ions (Na, K, Ca, Mg, alkalinity, chloride, SO_4), • Nutrients (NH_3 as N, NO_3, NO_2, NO_X) • Dissolved metals (chromium, copper, nickel, lead and zinc) • TRH and BTEXN • Total nitrogen (TN) and Total phosphorus (TP), • COD • PFAS
February	X		X		
March	X		X		
April	X	X	X	X	
May	X				
June	X				
July	X	X	X	X	
August	X				
September	X				
October	X	X	X	X	
November	X				
December	X		X		

9.3 Review of monitoring sites

This data review has identified a number of monitoring sites that could be removed from the monitoring program, as summarised in Table 9-3.

Table 9-3. Monitoring program sampling sites review summary

Sampling site	Justification for removal
Surface water	
SW2	As stated in Section 7.3, sampling of surface water site SW2 has only been possible once during the July 2016 to March 2020 monitoring period due to lack of water flow. Monitoring of this site was initiated in 2015 to investigate a seepage issue from the Stage 3/4 landfill. This issue has since been addressed and seepage at this location is no longer observed. It is proposed that this site be removed from the water quality monitoring program.
Wheel Wash	Wheel Wash water is not indicative of water discharging from the site.
Groundwater	
WW3	Located in the centre of SBWMF and east of Stage 3/4 landfill. Monitoring bore WW1 is immediately north of WW3, and the new GW16 nested bores are immediately to the south, and monitoring of this area can be represented by these bores.
WW5	Located on the western boundary and to the west of Stage 3/4 landfill. The GW13 nested bores are immediately to the south of WW5 and can be used to represent groundwater at this location.
WW7	Located to the north-west of Stage 3/4 landfill, and adjacent to WW6. WW7 is a shallow bore (i.e. <10 m) and is capturing the impacts from leachate intrusion, however these are being observed at WW6, a deeper bore of ~ 20.4 m (see Section 7.5). Several bores are located along the site boundary in the down gradient groundwater direction, and can be used to determine off site impacts (i.e. GW14 (nested), WW9 and GW15 (nested)).
WW10	Located adjacent to the nested GW15 bores on the northern boundary, to the north of Stage 3/4 landfill. Monitoring of this area can be represented by these bores.

During preparation of this data review, the GW6 nested bores were decommissioned due to the construction of the new Stage 6 landfill. The GW6 bores were replaced by GW16 nested bores (3m, 12m and 30m) in a nearby location and should be added to the monitoring program.

The proposed leachate treatment system, which is to be constructed over a 2 ha area adjacent and to the west of the existing leachate storage ponds at the SBWMF, will require specific monitoring of groundwater bores during construction and operations. Existing groundwater bores relevant to the location of the leachate treatment system include the nested GW1, GW2, GW14 and GW15 bores, and WW9 and WW13. Two additional nested groundwater bores are proposed to be constructed and are detailed in Table 9-4.

It is proposed that these bores be monitored on a monthly basis for an initial period of 12 months from their construction. These bores should then be incorporated into the SBWMF monitoring program at the frequency specified in Table 9-2.

Table 9-4. Proposed new groundwater bores for the leachate treatment system

Groundwater bore ID	Bore type	Location	Purpose
GW17-3 GW17-12 GW17-30	• 3 m (perched) • 12 m • 30 m	Within the proposed treatment plant area	Assess shallow and deep groundwater within the proposed plant area, and existing potential migration of impacted groundwater towards the site from leachate ponds. Additional deeper well to assess interconnectivity of sandstone and siltstone aquifers.
GW18-3 GW18-12	• 3 m (perched) • 12 m	Within the proposed treatment plant area	Assess shallow and deep groundwater within the proposed plant area.

10 REFERENCES

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URS 2016c, *Shoal Bay Waste Disposal Site Ecological Risk Assessment*, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd, March 2016.

APPENDIX A STANDARD OPERATING PROCEDURE, SHOAL BAY WASTE DISPOSAL SITE, WATER MONITORING

EcOz Environmental Consultants

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Standard Operating Procedure:

Shoal Bay Waste Disposal Site Water Monitoring

Prepared for City of Darwin









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Appendices

Appendix A – Surface Water / Leachate Field Data Sheet

Appendix B – Groundwater Field Data Sheet

Appendix C – Laboratory Chain of Custody Form

1 Introduction

1.1 Purpose

The purpose of this Standard Operating Procedure (SOP) is to ensure that all groundwater, surface water and leachate sampling specified in the *Shoal Bay Waste Disposal Site Water Monitoring Plan* (URS 2016) is undertaken in a consistent, quality controlled, and safe manner, and follows best-practice procedures in accordance with the relevant standards and guidelines.

The methodologies, timelines and contingencies outlined in this SOP also aim to ensure that the sampling schedule and reporting of analytical results meet the required monthly, quarterly and annual deadlines.

Water monitoring at the Shoal Bay Waste Disposal Site (the site) is required for compliance with the site's Environment Protection Licence (EPL12-09), issued by the Northern Territory(NT) Environment Protection Authority (EPA) under the NT *Waste Management and Pollution Control Act*.

1.2 Scope

This SOP applies to all groundwater, surface water, and leachate sampling undertaken by EcOz Environmental Consultants (EcOz) and Larrakia Rangers at the Shoal Bay Waste Disposal Site. Primarily, this SOP applies to all water sampling required for EPL compliance reporting, but also any ad hoc, incident, or special purpose water monitoring required at the site.

1.3 Legal requirements, standards and guidelines

This SOP has been developed in accordance with the following:

- URS 2016, *Shoal Bay Waste Disposal Site Water Monitoring Plan*, March 2016, Report prepared for John Holland Pty Ltd, URS Australia, Darwin, NT.
- Updated site information from City of Darwin (updated site map provided February 2020).
- NT EPA 2011, *Environment Protection Licence EPL12-09*, Issued 1 March 2011, Expires 1 July 2016, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.
- NT EPA 2013, *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.
- Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998), Standards Australia, New South Wales.
- Australian Standard on Water Quality Sampling - Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), Standards Australia, New South Wales.
- Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Standards Australia, New South Wales.
- Australian Standard on Water Quality Sampling – Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998), Standards Australia, New South Wales.
- Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998), Standards Australia, New South Wales.
- Sundaram, B., Feitz, A., Caritat, P. de, Plazinska, A., Brodie, R., Coram, J. and Ransley, T., 2009. *Groundwater Sampling and Analysis – A Field Guide*. Geoscience Australia, Record 2009/27 95 pp.
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- ANZECC & AMRCANZ 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

2 Methodology, Safety, Training and Quality Assurance

2.1 Groundwater, surface water and leachate sampling methodology

All sampling will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998).

2.1.1 Groundwater sampling

Groundwater sampling methods will comply with the Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998).

Groundwater sampling involves:

1. The measurement of physical parameters (pH, temperature, EC, DO, turbidity) in groundwater using hand-held YSI field water quality meters calibrated immediately prior to mobilisation to site, and
2. The collection of groundwater into laboratory-supplied sample bottles for sending to the laboratory for analysis.

Samples will be collected from groundwater bores using a micropurge/low-flow bladder pump in the first instance, or manual bailers if groundwater yields are insufficient to allow pumping. The micropurge/low-flow sampling set up comprises a QED MP50 drawdown controller, 12V DC compressor and QED Sample Pro portable micropurge pump. This type of system is proven for minimal effect on water chemistry and obtaining representative samples (Sundaram 2009). If manual bailing is required, disposable Clear-View PVC bailers will be used; a new bailer for each bore.

Experience gained from groundwater sampling undertaken by EcOz at numerous sites in the Darwin region shows that shallow bores with depths up to 20 m can be easily sampled with a low-flow bladder pump in the mid to late wet season (January-April) but pumping can become difficult in the dry season and early wet season (May-December), and manual bailers are sometimes required. Often shallow bores less than 20 m deep can be dry in the mid to late dry season and cannot be sampled. Similarly, surface water bodies dry up during the dry season and cannot be sampled.

In order to gain a representative sample of the surrounding groundwater aquifer quality and not stagnant water contained within the bore, the pump is lowered to within the screened interval, and the rate of pumping matched to the groundwater recharge rate; confirmed by constant monitoring of the standing water level (SWL), which must remain stable. Water quality parameters (pH, temperature, EC, DO, ORP) are constantly monitored in the groundwater as it is pumped from the bore using YSI water quality meters that have been calibrated immediately prior to mobilisation to site. Pumping is continued until readings stabilise i.e. until three consecutive readings of all parameters measured at 5 minute intervals stabilise to within 5% of each other. This usually takes at least 30 minutes of pumping. Low dissolved oxygen (DO) and negative oxidation reduction potential (ORP) are also indicators of fresh groundwater, and not water from within the bore casing which is in contact with the air. Once stable readings are achieved, samples for laboratory analysis are collected directly into laboratory-supplied bottles.

When using manual bailers, a dedicated bailer is used for each bore, and the bore is purged until dry and then sampled once the bore has recharged and SWL has returned to its original level. If recharge in the bore means it doesn't completely empty, then three x volumes worth of standing water in the bore must be removed and the original standing water level allowed to return prior to sampling.

2.1.2 Surface water and leachate sampling

Surface water and leachate sampling methods will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), and Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998).

Surface water and leachate sampling involves:

1. The measurement of physical parameters (pH, temperature, EC, DO, turbidity) using hand-held YSI field water quality meters calibrated immediately prior to mobilisation to site, and
2. The collection of water into laboratory-supplied sample bottles for sending to the laboratory for analysis.

The specific method of sampling differs depending on the water source. The five different types of water sources and corresponding sampling methods are:

- Surface water bodies, ponds, and drains with safe direct access – will be sampled directly by placing field water quality meters into the water body for physical parameters, and collecting water samples for laboratory analysis directly into the laboratory-supplied sample bottles (note for bottles with preservative, sample will be decanted into the bottle from one of the unpreserved laboratory-supplied bottles to prevent loss of preservative).
- Surface water bodies, ponds, and drains without safe direct access – will be sampled using a clean, decontaminated jug on a pole, and the physical parameters measured immediately from within the jug. The jug on a pole will then be rinsed in the sample water several times prior to collecting sample for decanting into the laboratory-supplied sample containers for laboratory analysis.
- Sumps without a pump – will be sampled using a clean, decontaminated jug on a pole (as explained above) or a dedicated bailer. When using a bailer, the sample is decanted into a clean, decontaminated jug for measuring physical parameters and the sample poured directly into laboratory-supplied sample containers for laboratory analysis.
- Sumps with a pump – will be sampled by turning the tap on and the sample going into a clean, decontaminated jug for measuring physical parameters and then poured directly from the tap into laboratory-supplied sample containers for laboratory analysis.
- Leachate pond risers – will be sampled using a submersible pump lowered into the riser with the sample going from the hose into a clean, decontaminated jug for measuring physical parameters and then directly from the hose into laboratory-supplied sample containers for laboratory analysis.

For surface water bodies and sumps sampled either directly or using a sample pole or bailer, samples will be collected approximately 0.3 m below the water surface. When collecting samples from flowing water bodies, the sample must be collected a reasonable distance from the water's edge and facing into the flow direction, keeping hands and sampler equipment downstream to prevent contamination.

Samples for metals analysis (both groundwater and surface leachate water) will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

2.2 Responsibilities

EcOz Environmental Consulting is responsible for overall coordination of the monitoring program, including sub-contractor management, liaising with the site manager, the quality of sample collection and handling prior to delivery to the laboratories, and the delivery of laboratory results and field data to the Waste Services Manager. EcOz must ensure that suitably skilled and experienced staff are available to complete the monitoring within the required timeframes, and that sampling equipment is always maintained in good working order ready for both routine and any ad hoc sampling required.

EcOz staff and Larrakia Ranger staff are responsible for undertaking the sampling in accordance with this SOP.

EcOz / Larrakia Rangers shall not disclose to any person, any information or documentation relating to the Principal of the affairs of others which may have come to its or their knowledge as a result of the works and shall take all necessary precautions to prevent unauthorised access to such information or documentation. EcOz / Larrakia Rangers shall not divulge any information regarding the nature of the works or give any publicity concerning the works except with the written consent of the Principal.

ALS Laboratories are responsible for the quality of sample handling and analysis once samples are received from EcOz / Larrakia Rangers. ALS are also responsible for undertaking all required within-laboratory quality assurance / quality control (QA/QC) procedures in accordance with their NATA accrediations, and timely delivery of analytical results. Similarly, Eurofins mgt laboratories is responsible for spilt (triplicate) samples sent to them for QA/QC purposes (i.e. inter-laboratory variability).

The Waste Services Manager is responsible for communicating any changes to the water monitoring plan that need to be reflected in changes to the sampling program. For example, changes requested by the NT EPA for compliance purposes. The Waste Services Manager is also responsible for communicating any safety issues or access issues at the site relevant to the monitoring activities, over and above those normally expected for the site. Having said this, EcOz acknowledges that all EcOz staff will take the utmost care to make themselves informed of the status of operations during the days when monitoring is being conducted, and to maintain communications with heavy vehicle and plant operators to avoid any incidents.

2.3 Health, safety and site access requirements

A specific Job Hazard Analysis (JHA) for the Shoal Bay Waste Disposal Site has been developed based on the standard hazard management outlined in Table 1. The JHA also includes details of personal protective equipment (PPE), such as:

- Sturdy boots (steel cap and laces)
- Hat, safety/polaroid sunglasses, sunscreen etc for sun protection
- Hard hat
- Long pants and shirt (high-visibility)
- Gloves for handling heavy equipment

For safety reasons, field sampling will always be undertaken by at least two personnel. All personnel undertaking the sampling will have current first-aid training and have completed a 4WD course and have hands-on, regular experience driving off-road.

The JHA is stored in EcOz's Document Management System (Vantage folder B0304). Prior to each monthly monitoring round, this JHA must be reviewed in relation to that specific month, any updates/changes made, and then printed out. The printed copy must be read, understood, and signed by all field party members, and also signed off by the Fieldwork Leader/Project Manager, EcOz OH&S Officer, and EcOz Manager. Completed and signed JHA's are saved in the Vantage VBM project folder B0304. A copy of the JHA must be taken into the field for reference when undertaking the works.

EcOz is deemed the Principal Contractor and shall at all times comply with its obligations under the *Work Health and Safety National Uniform Legislation Act* (NT Government). All EcOz/Larrakia Rangers will hold a White Card or otherwise comply with the *Northern Territory Code of Practice for Induction for Construction Work*.

EcOz has nominated Senior Environmental Consultant Emma Smith as its representative for the site. Emma will prior to the commencement of works undergo a site induction together with the Superintendent's representative and representatives of Territoria Civil; the landfill operator. EcOz's site representative shall then ensure that all employees and subcontractors involved in the water monitoring sampling program are similarly inducted to the site prior to commencing work.

Table 1. Standard hazard management for groundwater and surface water sampling

Job Steps	Potential Hazards	Hazard Management
Driving to and around site	Heavy vehicles and plant	• Always maintain radio communications with heavy vehicle and plant operators, or if not possible maintain a safe distance
	Site operations	• Discuss with site manager prior to each day's work site operational activities that may pose a hazard or restrict access to sampling locations • Pre-inform the site manager of the monitoring activities for that day and the specific areas to be accessed for sampling
	Animals on road	• Do not swerve to avoid hitting fauna on the road, slow down and maintain line • Avoid travelling on roads early morning, late afternoon and night
	Other vehicles	• Maintain good observation when driving • Even on quiet roads, always assume the possibility of an oncoming vehicle
	Road conditions	• Stay within speed limits and drive according to conditions
	Driver fatigue	• Regularly swap drivers and take breaks
	Flat tyres	• Carry spare tyres, jack and tools • All party members must be proficient in changing a tyre on the type of vehicle being used
	Getting lost	• Use GPS, maps and radio • Always work in pairs • Prepare scheduled call-in procedure prior to leaving office and abide by this procedure • Agree on procedure in the event of a missed call-in i.e. time to wait before calling emergency services
	Bogging	• Avoid driving in wet areas • Carry vehicle recovery equipment • At least one party member must be proficient safe use of recovery equipment • Maintain communications (i.e. radio channel 40, satphone) • Vehicle recovery only to be undertaken by personnel who have undertaken "4WD recovery training" • In areas of high risk, vehicles to travel in pairs, with the second vehicle not proceeding into boggy areas until first vehicle has made it through
	Mechanical failure	• Pre-start vehicle checks • Maintain communications (i.e. radio channel 40, satphone)
Groundwater and Surface water sampling	Unsafe worksite	• Upon arrival to each site, perform an assessment of potential risks/dangers unique to the area and mitigate accordingly (Take 5) • Add any new hazards to JHA
	Cuts/abrasions	• Wear full PPE when performing sampling
	Manual handling	• Use appropriate lifting techniques, e.g. straight back, bent knees when lifting equipment

Job Steps	Potential Hazards	Hazard Management
		• Lift equipment using two persons when appropriate
	Contaminated water	• Do not contact any surface or groundwater when sampling, use powder-free gloves
	Pump and compressor operation (12V micro purge system)	• Personnel must be inducted in the use of the groundwater sampling equipment • Perform pre-start on groundwater equipment (particularly pressure fittings, controller) • Take care when connecting power leads to vehicle – ensure vehicle is off and all wires are free from moving engine parts when vehicle is started • Minimum 2 staff to ensure lifting and retrieving can be done in team • Avoid pinch points when retrieving hoses • Always lock hose reel and place pump in holder when moving between sites
	Surface water site access	• Surface water bodies only to be sampled directly if safe to do so i.e. no steep, slippery banks, no risk of crocodiles, no toxic fumes/confined space. • If not safe, samples to be collected using sampling pole or an alternative method.
	Snakes	• Correct PPE (i.e. sturdy boots, long pants/gators) • All personal have first aid training • Care taken when stepping over logs • Each person to carry snake bandage at all times
	Feral animals (e.g. cattle, buffalo, pigs)	• Assess each site for potential dangerous animals upon arrival (Take 5) • Maintain safe distance from any animals • Shelter in vehicle if required
	Ticks	• Check body and clothing for ticks at the end of each day • Shirts to remain tucked into the trousers • Advising other personnel of the locations where ticks have been seen/recorded • Ticks to be carefully removed to avoid squeezing the tick • Seek medical advice if a tick bite is found
	Tripping / slipping / strains	• Care taken walking in rough / overgrown terrain (or seek alternative route) • Use appropriate lifting techniques (i.e. bend knees), 2 person lifts and lift within capabilities
	Dehydration / heat exhaustion	• Adequate water and electrolyte replacement carried for all personnel and personnel to maintain their fluid levels • Competent first aid trained person within sampling group • Correct PPE • First aid is readily available
	Burns (re-fuelling)	• Ensure that re-fuelling takes place in an open area • Fire extinguisher fitted in each vehicle • Engine off • First aid kit carried • Competent first aid trained person within sampling group • Ensure no ignition sources are nearby (e.g. radios,

Job Steps	Potential Hazards	Hazard Management
		monitoring equipment)
	Lightning	• Sampling must stop and the field party return to the site office if lightening within 10 km of the site i.e. less than 10 sec gap between lightning and thunder. Works not to recommence until lightning moves further than 10 km away.
	Sunburn and biting insects	• Use sunscreen and insect repellent and wear correct PPE (i.e. hat, long sleeves, long pants)

2.4 Personnel, training and competency

Two EcOz/Larrakia Ranger staff will be required to undertake the sampling for both safety and time efficiency reasons. All personnel conducting the sampling shall be familiar with this SOP, and be experienced in the sampling procedures and strict QA/QC requirements to prevent sample contamination and obtain representative samples. All personnel will also have prior experience in calibrating and operating the hand-held field water quality meters, groundwater sampling using the compressor and low-flow bladder pump set-up and manual bailers, and grab sample collection from surface water bodies.

2.5 Quality assurance summary

The quality, accuracy and representativeness of samples and analytical results is assured given the following:

- All sampling will be carried out by well-experienced local EcOz / Larrakia Ranger personnel who have undertaken both groundwater and surface water sampling at numerous commercial/industrial sites across the Darwin region and who have in-depth, hands-on knowledge of the nature of groundwater aquifers and surface water bodies and run-off, seasonal variations, and logistical and safety requirements.
- EcOz's groundwater sampling set up (micropurge/low flow pump) and groundwater sampling procedure is the most effective in obtaining representative samples in the type of bores and aquifer system at the Shoal Bay site. Also, stringent procedures are followed to ensure the actual groundwater aquifer is being sampled and not stagnant water within the bore casing; where groundwater pumping is matched to the recharge rate (i.e. no drawdown) and water quality parameters (pH, temperature, EC, DO, ORP) must stabilise to with 5% for three consecutive 5 minute readings before sample collection. If manual bailers are required due to poor recharge, the bore must be emptied, or three x bore volumes worth of water removed and allowed to recharge prior to sample collection.
- Field QA/QC samples will be collected as per Section 3.4 below, and also the laboratories ALS / Eurofins mgt have stringent internal QA/QC procedures in accordance with their NATA accreditation. Field QA/QC results and internal laboratory QA/QC results will be provided along with the sample results.
- To prevent contamination of samples during field collection;
    - sampling personnel will wear powder-free disposable gloves (a new pair for each sample),
    - disposable syringes and field filters will be used for filtering metals samples,
    - samples will be collected into laboratory-supplied, pre-preserved containers,
    - all equipment that is re-used (e.g. groundwater pump and hoses) will be rinsed with Decon 90 and deionised water between bores/sample sites,

- wherever possible, samples will be collected directly into sample containers negating the need to clean equipment between samples, e.g sample goes directly into bottles from groundwater pump hose, and samples are collected directly from surface water bodies,
- when filling sample containers, whilst the lid is off, the lid will not be placed edge-down in contact with any surfaces, and nothing will be allowed to contact the opening of the bottle,
- all sampling equipment and hands will be kept downstream of where samples are collected in surface water bodies.

- Once collected, samples will be kept cool in eskies with frozen ice-bricks until drop off at the laboratory shopfront, after which they will be kept refrigerated <4°C until analysed. Ice is not to be used in eskies as melted ice can contaminate the samples.
- All samples will be delivered to the laboratories to allow for analysis to be undertaken within holding times (see Table 13 below). The shortest holding time is two days for BOD, nitrate, nitrite and phosphorus. In order to allow samples to be delivered to the interstate laboratories and meet this holding time, samples with these parameters (i.e. all quarterly and annual samples) will need to be delivered to the Darwin ALS / Eurofins mgt shopfront by 3 pm each day and not on a Friday, Saturday or Sunday. As such, sampling will need to start very early (7 am) and be completed in four days (Mon/Tues/Wed/Thurs). If sampling is not completed on Thursday, it will need to be finished the following Monday. The shortest holding time for monthly samples is 14 days, therefore sample delivery to the laboratories by 3 pm is not critical but this will be achieved if possible.
- Strict chain of custody (COC) procedures and documentation will be maintained and provided along with results.

2.6 Contingencies

Achieving the required monthly/quarterly/annual monitoring rounds within the required timeframe i.e. sampling in the first week of the month and results delivered by the last week of the month, is assured by the large pool of EcOz/Larrakia Ranger staff available who are well-experienced in groundwater and surface water sampling. At least seven EcOz staff are available and five Larrakia Rangers. This large pool of staff also means that any emergency incident or extra ad hoc sampling can be undertaken at short notice when required. Similarly, all groundwater and surface water sampling equipment, laboratory bottles and documentation (COCs, JHAs, Field Data Sheets) are well maintained and ready for mobilisation at short notice. This includes having at least two groundwater pump set-ups, and sets of water quality meters so that if they are already in use for another job, there is still a set available.

It is not envisaged that weather presents a high risk to the undertaking of sampling, given that groundwater, surface water and leachate sampling can still occur if it is raining and all sampling is undertaken using a 4WD vehicle with recovery gear and staff who are well-experienced in challenging 4WDing conditions. EcOz also owns several All-Terrain Vehicles and side-by-side off-road vehicles, which can be used if required.

An extreme storm event, or cyclone may mean that sampling is postponed, but in this case EcOz would endeavour to still achieve results delivery by the last week of the month by commencing sampling as soon as it is safe to do so, even if working over a weekend is required. Similarly, if works or operations on site mean that groundwater bores and/or surface water / leachate sites are inaccessible, EcOz would sample any sites which are not affected by the works first in consultation with the site manager, and then sample the remaining sites as soon as they become accessible again.

EcOz has a long established and good working relationship with both ALS and Eurofins mgt Laboratories. This ensures quick follow-up in the case of any inquiries regarding sample results, and also a quick response to any requests for extra or unusual analysis etc. EcOz is a valued client of these laboratories; given the amount of work we bring them, and as such, we are given a discount on analytical costs.

3 Sampling Overview

3.1 Sampling schedule

Groundwater, surface water and leachate sampling is undertaken monthly, with differing parameters analysed on a monthly, quarterly and annual basis (see Tables 3 to 11). Sampling must be undertaken in the first week of each month, noting that this is taken to represent the previous month e.g. sampling undertaken in the first week of July is taken to represent June. Sampling in the first week of each month ensures that laboratory analytical results are completed and sent to the Waste Services Manager by the final week of each month. It is estimated that for each monthly monitoring round, all groundwater, surface water and leachate samples will take 4 to 5 days to collect; less depending on the number of dry bores and surface water sites.

Figure 1 shows the sampling schedule. The annual sampling round, comprising a larger suite of analysis, is timed to coincide with the time of maximum wet season rainfall; typically January in the Darwin region. Note this would be the sampling round undertaken in the first week of February. This is the time of maximum recharge to groundwater bores and is likely to reflect the cumulative effect of any contamination entrained in wet season rainfall, run-off and infiltration.

The shortest holding time for the suite of analytical parameters is two days for quarterly and annual sampling, and 14 days for monthly sampling. In order to allow samples to be delivered to the interstate laboratories and meet the two day holding time, samples will need to be delivered to the Darwin ALS / Eurofins mgt shopfront by 3 pm each day and not on a Friday, Saturday or Sunday. As such, sampling will need to start very early (7 am) and be completed in four days (Mon/Tues/Wed/Thurs). If sampling is not completed on Thursday, it will need to be finished the following Monday. For monthly sampling, a Monday to Friday sampling timeframe is acceptable, with sample delivery by COB each day.

	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
MONTHLY												
QUARTERLY												
ANNUAL												

Figure 1. Monthly/Quarterly/Annual sampling schedule

3.2 Sampling sites

The water monitoring program includes the sampling of 37 groundwater bores, five surface water sites, and eight leachate sites. Site locations are shown in Figure 2, and coordinates listed in Table 2 and Table 3. Relevant bore construction details are also provided in Table 2.

The 37 groundwater monitoring bores are located at 21 different sites i.e. most sites have more than one bore (see Figure 2). For the 29 bores with the identifier "GW" the number of bores at each site is either two or three bores, with each bore being a different depth, i.e. 3 m, 12 m and up to 30 m deep. The 8 bores with the identifier "WW" exist as a single bore at each site with varying depths between 5.8 and 20.3 m.

As mentioned in Section 2.1.2 above, the specific method of sample collection for surface water / leachate sites differs depending on the site as outlined below:

- Surface water bodies, ponds, drains include the sites: SW2, SW12, STG1&2 and GW Sump
- Sumps without a pump: Wheel Wash, LMP02
- Sumps with a pump and tap: DW2, DW3, DW5, DW6 and TC Sump
- Leachate ponds with riser: LP01 and LP02
- Leachate seepage sites : LS5A and LS5B

Importantly to note in planning is that it is unlikely that during the dry season, all groundwater bores and surface water sites can be sampled, as once wet season rains cease in April/May, the groundwater table can lower further than the base of the bores and surface water bodies i.e. they are dry. Similarly, some surface water sites are dry during the dry season.

Also, during the wet season, access to some sites may become boggy and EcOz's All-Terrain Vehicles or side-by-side off-road vehicles may be required.



Figure 2. Map of SBWMF Water Monitoring Sites

Table 2. Sample location coordinates and bore construction details. (adapted from URS 2016)

Bore	Easting (m)*	Northing (m)	Monument Elevation (m AHD)	PVC Elevation (m AHD)	Ground Elevation (m AHD)	Screened Interval (m bgl)	Screened Interval Lithology
GW1-3	709564	8631004	8.71	8.63	8.02	1.5 - 3	Siltstone
GW1-12	709566	8631004	8.71	8.59	8.00	9 - 12	Siltstone
GW2-3	709629	8630835	8.06	7.94	7.33	1.5 - 3	Siltstone
GW2-12	709631	8630835	8.08	7.94	7.28	9 - 12	Siltstone
GW3-3	709652	8630746	9.94	9.80	9.12	1.5 - 3	Siltstone
GW3-12	709654	8630746	9.87	9.82	9.10	9 - 12	Siltstone
GW4-3	709775	8630634	5.65	5.49	4.88	1.5 - 3	Siltstone
GW4-12	709776	8630633	5.61	5.44	5.36	9 - 12	Siltstone
GW4-30	709777	8630631	5.50	5.20	5.33	15 - 21	Gravelly Sand, Sandstone
GW5-3	709880	8630224	5.51	5.41	4.70	1.5 - 3	Siltstone
GW5-12	709880	8630226	5.48	5.33	4.70	9 - 12	Siltstone, Gravelly Clay
GW7-3	709900	8629992	5.18	5.03	4.33	1.5 - 3	Siltstone
GW7-12	709900	8629994	5.16	5.08	4.33	9 - 12	Siltstone, Sandy Silt
GW8-3	709896	8629708	5.42	5.28	4.65	1.5 - 3	Claystone
GW8-12	709896	8629708	5.37	5.22	4.62	9.1 - 12.1	Claystone, Sandstone
GW9-12	709660	8629469	16.18	15.93	15.44	9 - 12	Siltstone
GW10-3	709147	8629507	18.12	18.06	17.32	1.5 - 3	Siltstone
GW10-12	709149	8629507	18.13	17.98	17.37	9.1 - 12.1	Siltstone
GW11-3	709040	8629671	13.50	13.38	12.72	1.5 - 3	Siltstone
GW11-12	709042	8629671	13.52	13.38	12.84	9 - 12	Siltstone, Sandstone
GW12-3	709024	8629881	12.20	12.07	11.44	1.5 - 3	Siltstone
GW12-12	709024	8629883	12.22	12.04	11.50	9 - 12	Siltstone
GW12-30	709024	8629885	12.21	12.05	11.55	24 - 30	Sandstone
GW13-3	709017	8630175	12.93	12.88	12.32	3 - 4.5	Siltstone
GW13-12	709016	8630174	12.91	12.86	12.25	10 - 13.5	Siltstone
GW14-3	709013	8630423	6.78	6.73	6.09	1.5 - 3	Siltstone
GW14-12	709013	8630424	6.77	6.64	6.08	9 - 12	Siltstone

Bore	Easting (m)*	Northing (m)	Monument Elevation (m AHD)	PVC Elevation (m AHD)	Ground Elevation (m AHD)	Screened Interval (m bgl)	Screened Interval Lithology
GW15-3	709230	8630599	11.27	11.06	10.44	1.5 - 3	Siltstone
GW15-12	709233	8630599	11.20	11.04	10.44	9 - 12	Siltstone
WW1	709471	8630255	-	-	15.90	0 - 6.3	-
WW3	709471	8630151	-	-	15.68	0 - 20.3	-
WW5	708980	8630234	-	-	7.64	0 - 6.0	-
WW7	709045	8630483	-	-	6.75	0 - 5.8	-
WW9	709016	8630598	-	-	6.39	0 - 9.8	-
WW10	709235	8630598	-	-	10.21	0 – 9.7	-
WW13	709457	8630598	-	-	-	0 – 10 (Appox)	-

Table 3: Updated site information for additional groundwater bores, and all surface water and groundwater sites (updated February 2020)

Sample site	Easting (m)	Northing (m)	Comment
WW6	709085	8630448	Groundwater bore
SW2	708973	8630296	Surface water site West of Stage 4
SW12	709035	8630495	Surface water site Northwest of Stage 4
SW13	709065	8630504	Surface water (North Dam)
SW14	709287	8630536	Surface water (Borrow Pit)
SW Stg 1&2	709448	8629979	Surface water site Surface drain between Stage 1 and 2
GW Sump	709102	8629880	Surface water site Greenwaste area
Wheel wash	709479	8629755	Surface water site
LP01	709534	8630726	Leachate site
LP02	709531	8630713	Leachate site
LMP02	709938	8629759	Leachate site East of Stage 1
DW2	709029	8630459	Leachate site Deleaching well Stage 3.3
DW3	709038	8630216	Leachate site
DW5	709023	8630122	Leachate site
DW6	709041	8630039	Leachate site
TC SUMP	709465	8630233	Leachate site
LS5A	708994	8630070	Leachate site
LS5B	708950	8630108	Leachate site

3.3 Sampling equipment

- **Copy of this SOP**
- **Copy of the Job Hazard Analysis (JHA)** must be signed
- **Maps** (monitoring site locations see Figure 2)
- **Site Coordinates** (see Table 2 and Table 3)
- **GPS** (handheld); spare batteries
- **Any site access or permit requirements** such as keys, ID Cards, White Card, Contractor Induction Certificates
- **Folder/clipboard, Field Data Sheets** (see Appendix A and B), enough for allsites plus spares; all printed on waterproof paper
- **Chain of Custody (COC)** forms (See Appendix C)
- **Stationary**: Pens / pencils, **permanent markers** (xylene-free) for completing sample bottlelabelling
- **Sample containers** obtained from ALS / Eurofins mgt as per Section 3.6. Enough for all sample sites, QA/QC samples and some spares
- **YSI field water quality meters** (pH, EC, temperature, DO, ORP, Turbidity) calibrated each day prior to mobilising to site
- **Plastic jugs**
- **Sample pole**
- **Syringes and Filters** (for sampling dissolved metals)
- **Eskies** with frozen ice bricks; enough for the entire days' worth of samples
- **Camera** fully charged
- **Decon 90** solution mixed with deionised water (1:20) and **Plastic tub** to clean equipment between samples
- **Disposable powder-free gloves**
- **PPE** see JHA
- **Garbage bag** for general waste generated during sampling
- **Communications** equipment (e.g. mobile/satellite phone, radio, EPIRB)

Groundwater-specific sampling equipment:

- **Pump, hose reel and compressor set-up**
- **Flow cell**
- **New disposable bailers – enough for one for each bore requiring bailing**
- **Bore construction reports for each bore**
- **Fox whistle or electronic dip meter for measuring standing water level (SWL)**
- **Bucket (20 L)**
- **Hand tools to open bore caps and keys if bores are locked**
- **Calculator and Watch/time keeper**

3.4 Quality Assurance / Quality Control Samples

QA/QC samples will comprise:

a) Field duplicate samples at 1 per 10 water samples per monitoring event;

b) Field triplicate samples 1 per 20 water samples per monitoring event; the split sample will be analysed by Eurofins mgt

c) Field rinsate samples at 1 per day;

d) Field blank samples at 1 per day; and

e) Trip blanks 1 per esky containing samples scheduled for volatile analysis.

3.5 Sample nomenclature

Samples will be labelled on sample bottles, and in all laboratory documentation and results according to the site names listed in Table 2 and Table 3. Duplicates and triplicates will be labelled as "Duplicate 1", Duplicate 2", "Triplicate 1" etc, and the site where the duplicate/triplicate sample was taken identified on the Field Data Sheets. Trip blanks will be labelled "Trip Blank dd/mm/yyyy". The date is included to identify which batch of samples the trip blanks accompanied.

3.6 Analytical parameters, sample containers and holding times

Tables 4 to 14 provide details of the analytical parameters and limits of reporting (LOR) for monthly/quarterly/annual groundwater, surface water and leachate sampling. Table 13 outlines the required sample containers, and Table 14 the holding times for each parameter.

Table 4. Monthly groundwater analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Cations: Calcium, Magnesium, Sodium, Potassium	NT-1	APHA 3120B or 3125B	1
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl^- -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10

Table 5. Monthly surface water analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl^- -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10

Table 6. Monthly leachate analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10

Table 7. Quarterly groundwater analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Cations: Calcium, Magnesium, Sodium, Potassium	NT-1	APHA 3120B or 3125B	1
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl^- -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Nitrite as N	NT-4	APHA 4500 NO_2- - I	0.01
Nitrate as N		APHA VCl3 reduction 4500 NO_3- + NO_2-B	0.01
Organic Nitrogen as N (calculation of TKN - Ammonia)	EK060	APHA 4500 Norg /NH_3	0.1
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Phosphorus Reactive as P	EK071	APHA 4500 P – F	0.01
ICP/MS (dissolved): Cd, Cr, Cu, Pb, Fe, Mn, Ni, Zn	EG020F	USEPA 6020 ICP/MS	Cd: 0.0001 Zn: 0.005 Other: 0.001
Trivalent Chromium *(must be requested with Hex' Cr and dissolved Cr)*	EG049	APHA 3500 Cr- A & B	0.01
Hexavalent Chromium - Dissolved	EG050	APHA 3500 Cr-B	0.01
Iron - Ferrous (dissolved)	EG051	APHA3500 Fe-B	0.05
Iron - Ferric (dissolved)	EG053	Calc from dissolved and ferrous.	0.05
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10
TPH (C6-C36) plus TRH (C6-C40)	EP080/071	USEPA 8260/8015 P&T-GC/MS/FID APHA 5520F	20-100 (µg/L)
PAH - Standard level *(16 analytes)*	EP075B (SIM)	USEPA 3510/8270	0.5-1 (µg/L)
PFAS – 28 analytes	EP231X	In house LC/MS-MS	0.002-0.01 (µg/L)

Table 8. Quarterly surface water analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl^- -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10

Table 9. Quarterly leachate analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Cations: Calcium, Magnesium, Sodium, Potassium	NT-1	APHA 3120B or 3125B	1
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl^- -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Nitrite as N	NT-4	APHA 4500 NO_2- - I	0.01
Nitrate as N		APHA VCl3 reduction 4500 NO_3- + NO_2-B	0.01
Organic Nitrogen as N (calculation of TKN - Ammonia)	EK060	APHA 4500 Norg /NH_3	0.1
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Phosphorus Reactive as P	EK071	APHA 4500 P – F	0.01
ICP/MS (dissolved): Cd, Cr, Cu, Pb, Fe, Mn, Ni, Zn	EG020F	USEPA 6020 ICP/MS	Cd: 0.0001 Zn: 0.005 Other: 0.001
Trivalent Chromium *(must be requested with Hex' Cr and dissolved Cr)*	EG049	APHA 3500 Cr- A & B	0.01
Hexavalent Chromium - Dissolved	EG050	APHA 3500 Cr-B	0.01
Iron - Ferrous (dissolved)	EG051	APHA3500 Fe-B	0.05
Iron - Ferric (dissolved)	EG053	Calc from dissolved and ferrous.	0.05
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10
TRH (C6-C40)/BTEXN/PAH	W-7	GC/FID, P&T- or HS-GC/MS,GC/MS-SIM	TPH: 20-100µg/L BTEX:1-5µg/L PAH: 0.5-1µg/L
Phenolics - Total	EP035	APHA 5530 B&D	0.05
PFAS – 28 analytes	EP231X	In house LC/MS-MS	0.002-0.01 (µg/L)

Table 10. Annual groundwater analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Cations: Calcium, Magnesium, Sodium, Potassium	NT-1	APHA 3120B or 3125B	1
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl⁻ -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Nitrite as N	NT-4	APHA 4500 NO_2- - I	0.01
Nitrate as N		APHA VCl3 reduction 4500 NO_3- + NO_2-B	0.01
Organic Nitrogen as N (calculation of TKN - Ammonia)	EK060	APHA 4500 Norg /NH_3	0.1
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Phosphorus Reactive as P	EK071	APHA 4500 P – F	0.01
ICP/MS (dissolved): Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn	EG020F	USEPA 6020 ICP/MS	Cd: 0.0001 Zn: 0.005 Other: 0.001
Trivalent Chromium *(must be requested with Hex' Cr and dissolved Cr)*	EG049	APHA 3500 Cr- A & B	0.01
Hexavalent Chromium - Dissolved	EG050	APHA 3500 Cr-B	0.01
Iron - Ferrous (dissolved)	EG051	APHA3500 Fe-B	0.05
Iron - Ferric (dissolved)	EG053	Calc from dissolved and ferrous.	0.05
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10

Table 11. Annual surface water analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Cations: Calcium, Magnesium, Sodium, Potassium	NT-1	APHA 3120B or 3125B	1
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl^- -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Nitrite as N	NT-4	APHA 4500 NO_2- - I	0.01
Nitrate as N		APHA VCl3 reduction 4500 NO_3- + NO_2-B	0.01
Organic Nitrogen as N (calculation of TKN - Ammonia)	EK060	APHA 4500 Norg /NH_3	0.1
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Phosphorus Reactive as P	EK071	APHA 4500 P – F	0.01
ICP/MS (dissolved): Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn	EG020F	USEPA 6020 ICP/MS	Cd: 0.0001 Zn: 0.005 Other: 0.001
Trivalent Chromium *(must be requested with Hex' Cr and dissolved Cr)*	EG049	APHA 3500 Cr- A & B	0.01
Hexavalent Chromium - Dissolved	EG050	APHA 3500 Cr-B	0.01
Iron - Ferrous (dissolved)	EG051	APHA3500 Fe-B	0.05
Iron - Ferric (dissolved)	EG053	Calc from dissolved and ferrous.	0.05
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10

Table 12. Annual leachate analytical parameters, method references and limits of reporting from ALS Laboratories.

Parameter	ALS Code	Technique/ Method Reference	LOR (mg/L) (or as indicated)
Cations: Calcium, Magnesium, Sodium, Potassium	NT-1	APHA 3120B or 3125B	1
Sulfate - (Turbidimetric) as SO_4	NT-2	APHA 4500 SO4-E	1
Chloride - standard		APHA 4500-Cl⁻ -G	1
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$		APHA 2320 B	1
Nitrite as N	NT-4	APHA 4500 NO_2- - I	0.01
Nitrate as N		APHA VCl3 reduction 4500 NO_3- + NO_2-B	0.01
Organic Nitrogen as N (calculation of TKN - Ammonia)	EK060	APHA 4500 Norg /NH_3	0.1
Ammonium *(Calc:Field pH & temp provided by client)*	EK055G-NH4	Calculation	0.01
Phosphorus Reactive as P	EK071	APHA 4500 P – F	0.01
ICP/MS (dissolved): Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn	EG020F	USEPA 6020 ICP/MS	Cd: 0.0001 Zn: 0.005 Other: 0.001
Trivalent Chromium *(must be requested with Hex' Cr and dissolved Cr)*	EG049	APHA 3500 Cr- A & B	0.01
Hexavalent Chromium - Dissolved	EG050	APHA 3500 Cr-B	0.01
Iron - Ferrous (dissolved)	EG051	APHA3500 Fe-B	0.05
Iron - Ferric (dissolved)	EG053	Calc from dissolved and ferrous.	0.05
Organic Carbon Total (TOC)	EP005	APHA 5310 B	1
Chemical Oxygen Demand (COD)	EP026	APHA 5220 B	10
TRH (C6-C40)/BTEXN/PAH	W-7	GC/FID, P&T- or HS-GC/MS,GC/MS-SIM	TPH: 20-100µg/L BTEX:1-5µg/L PAH: 0.5-1µg/L
Phenolics - Total	EP035	APHA 5530 B&D	0.05
PCB Total - Standard level	EP066	USEPA 3510/8270 GC/ECD/ECD/ MS	1 (µg/L)
Explosives *(18 analytes including TNT, RDX)* - Standard level	EP203	USEPA 8330 LC/MS	20-200 (µg/L)
Volatile Acids as Acetic Acid (CH_3COOH)	EP045	5560 C	5
BOD - Biochemical Oxygen Demand	EP030	APHA 5210 B	2

Table 13. Sample container and volume requirements.

Volumes listed below are recommended based on "clean" waters. Please contact ALS for further advice on sample volumes.			
		INORGANICS	
No.	*Label Colour*	Container Type (*Preservation noted if required*)	Test Parameter(s)
	Green	250mL plastic	Alkalinity, EC, pH, Cations, Cl, SO4, F, Nitrite, Nitrate, Reactive P
	Green	500mL plastic	As above plus std. level TDS, BOD
	Purple	60mL plastic (H_2SO_4 acid)	NOx, Ammonia and Total Phenolics or TKN/TP, NOx, COD
	Purple	40mL Glass vial (H_2SO_4 acid)	TOC
		METALS & RADIONUCLIDES	
No.	*Label Colour*	Container Type (*Preservation noted if required*)	Test Parameter(s)
	Red	60mL plastic (HNO_3 acid)	Metals/Cations Dissolved(Field Filtered) or Total
	Red & Green	60mL plastic AIRFREIGHT OPTION	Metals/Cations Dissolved(Field Filtered) or Total
	Maroon	60mL plastic (HCl acid)	Ferrous Iron (Field Filtered)
	Blue	60mL plastic (NaOH)	Hexavalent Chromium (Field Filtered)
		MICRO & ALGAE	
No.	*Label Colour*	Container Type (*Preservation*)	Test Parameter(s)
	Grey	250mL Sterile plastic jar/lid (With $Na_2S_2O_3$)	Multiple 'Micro' Tests.
		ORGANICS	
No.	*Label Colour*	Container Type (*Preservation noted if required*)	Test Parameter(s)
	Purple	Pairs of 40mL glass vials (Sulfuric Acid)	TPH/TRH(C6-C10), BTEXN, VOCs, Alcohols, Gases or Methane or CWG (VOC) speciation
	Orange	100mL glass bottle (primary test). Note: Additional 2 bottles required for QA/QC NOTE 1	Std TRH(C10-C40)/PCB/PAHs/Phenols
	Green & White Stripe	100mL glass bottle includes QA/QC NOTE 1	Standard Level LCMS testing including Explosives
	Grey	2 x 20mL plastic	PFAS or TOP Assay (standard level)

Table 14. Sample holding times.

Parameter	Holding Time
Total Dissolved Solids	7 Days
Ammonium *(Calc"Field pH & temp provided by client)*	28 Days
Cations: Calcium, Magnesium, Sodium, Potassium	28 Days
Sulfate - (Turbidimetric) as SO_4	28 Days
Chloride - standard	28 Days
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as $CaCO_3$	14 Days
Organic Carbon Total (TOC)	28 Days
Chemical Oxygen Demand (COD)	28 Days
Nitrate as N	2 Days
Organic Nitrogen as N	28 Days
Phosphorus Reactive as P	2 Days
Metals	180 Days
Trivalent Chromium	28 Days
Hexavalent Chromium	28 Days
Iron - Ferrous (dissolved)	7 Days
Iron - Ferric (dissolved)	7 Days
TPH (C6-C36) plus TRH (C6-C40)	7 Days
PAH - Standard level *(l6 analytes)*	7 Days
Phenolics - Total	28 Days
BOD - Biochemical Oxygen Demand	2 Days
PCB Total - Standard level	7 Days
Explosives *(l8 analytes including TNT, ROX)* - Standard level	7 Days
Volatile Acids as Acetic Acid (CH_3COOH)	14 Days
PFAS	180 days

3.7 Additional parameters

Additional parameters will need to be analysed in quarterly and annual groundwater and surface water samples if leachate impacts are observed. Leachate impacts are indicated where the L/N ratio is greater than 10. The L/N ratio is the ratio of leachate ions (L) such as K^+, NH_4^+ and NO_3^-, to natural groundwater ions (N) such as Ca^{2+}, Na^+ and Mg^{2+}.

$L/N = (K^+ + NH_4^+ NO_3^-) / (Ca^{2+} + Na^+ + Mg^{2+}) *100$

If the L/N ratio is greater 10 the additional parameters BTEXN and total phenolics will need to be analysed in quarterly groundwater samples, and the following parameters in the annual groundwater and surface water samples: TRHs, PAHs, BTEXN, total phenolics, BOD, VFA, PCB, TNT, RDX.

3.8 Reporting

Sampling will be undertaken during the first week of each month and sample analysis will be completed and results emailed to the Waste Services Manager by the last week of the month at the latest.

Samples will be submitted to the laboratories with a "standard" turn-around-time, which is estimated at 10 business days for the particular suite of analysis requested. Sample batches will be submitted to the laboratory shopfront on a daily basis during the sampling campaign, therefore results from the first day of sampling will be received first etc. Laboratory results and documentation will be emailed to the Waste Services Manager immediately upon receipt. In addition, if particular parameters are completed before others, these preliminary results will be sent to the Waste Services Manager as they are received.

All raw laboratory results and laboratory documentation will be forwarded including excel spreadsheets, chain of custody (COC) forms, certificate of analysis (COA), sample receipt notifications (SRN) and QA/QC documentation.

All Field Data Sheets will be scanned and sent to the Waste Services Manager upon completion of the last day of sampling for each monthly round i.e. at the end of the first week of the month. All site photos and other relevant photos will also be sent.

Following each monthly round, an email report will be submitted to the Waste Services Manager which will include a summary of sampling undertaken and a brief summary of results, with any exceedances of applicable trigger values noted.

Following each quarterly round, a formal report will be developed which will include:

- Summary of sampling undertaken (e.g. number of sites sampled, dates of sampling)
- Tabulation of results, and graphical representation if appropriate
- Comparison of results with applicable trigger values, highlighting any exceedances
- Trend analysis and comparison of results to historical data
- Interpretation of results, overall conclusions and recommendations

An annual report may be undertaken based on request from City of Darwin.

4 Step-by-step Procedure

4.1 Preparation prior to commencement

4.1.1 Confirm with Waste Services Manager the dates for sampling and discuss any potential site access issues.

4.1.2 Look at weather forecast in relation to sampling safety and the ability to obtain samples.

4.1.3 Ensure that JHA has been completed and that all staff involved have read, understood and signed the printed JHA.

4.1.4 Get together all the equipment listed in Section 3.3 (and any additional monitoring round-specific equipment) ready to go, ideally packing most of the gear together into a large plastic crate.

4.1.5 Bottles may need to be ordered from the laboratory (i.e. ALS and Eurofins mgt) if not already in stock in EcOz storeroom.

4.1.6 Put together a package of sample bottles for each site (i.e. in a large snap-lock bag), including bottles for duplicates, split/triplicate samples and blanks.

4.1.7 Calibrate the field test meters (e.g. pH, EC, Turbidity, DO, ORP) according to the laminated instruction card provided in the Calibration Folder and/or manufacturer's instructions. Fill out the *EcOz Calibration Record Sheet* and file in the Calibration Record Sheet Folder.

4.1.8 Ensure camera and GPS are fully charged and have a cleared memory.

4.1.9 Prepare a sufficient volume of Decon 90 solution (i.e. 1:20 Decon:de-ionised water) to use for cleaning sampling equipment in the field.

4.1.10 Print out required number of blank Field Data Sheets (Appendix A and B), COC forms (Appendix C), maps and bore reports.

4.1.11 Ensure that ice bricks have been put in the freezer for transfer to eskies on the morning of each sampling day.

4.1.12 Test run the groundwater pump at the EcOz shed to ensure everything is working properly.

4.1.13 Complete pre-start checks using the *EcOz Vehicle Pre-Start Checklist* on all vehicles being used i.e. 4WD vehicle and if required ATV or side-by-side.

4.2 Surface water / leachate sampling

4.2.1 Proceed to sample site using map (Figure 2), coordinates (Table 2 and Table 3) and GPS.

4.2.2 Record on field sheets the date, time, site name/number, sampler's name, and field observations such as weather conditions, water colour, clarity, water depth, flow rate, any obvious pollution (e.g. rubbish, odours, surface films etc.), flora/fauna, and any other issues that may affect the samples.

4.2.3 Put on disposable powder-free gloves.

4.2.4 Ideally, in-situ readings (e.g. pH, Temperature, DO, Turbidity, and EC) are collected directly from the water body being sampled by immersing the meters in the area to be sampled. However, if safety

and/or logistical issues preclude this, field readings may need to be taken from the sampling jug.

4.2.5 Record the in-situ parameters just below the water surface (between 0.2 and 0.5 m depth), depending on water depth. Alternatively, if collecting samples from various depths (e.g. depth profiling), ensure the field meter is lowered to the desired depth.

4.2.6 If collecting field readings from the sampling jug, collect a representative water sample using the jug mounted on a sampling pole. Ensure that the jug/sampler is fully immersed and rinsed at least 3 times, tipping the rinse water away from where the sample is to be collected (e.g. on the bank).

4.2.7 If sampling flowing waters, ensure that you are standing downstream of where you are sampling so as not to contaminate the sample.

4.2.8 Record all the readings on the Field Data Sheet (Appendix A).

4.2.9 Note that the procedure above is for the surface water bodies, ponds, and drains with direct access. Please refer to Sections 2.1.2 and 3.2 above for the slightly differing methods for the sumps without a pump, sumps with a pump, and the leachate ponds.

4.3 Sample collection

4.3.1 Ensure gloves are on.

4.3.2 Take out the snap-lock bag full of sample bottles for the site and fill in the required information on the labels with the permanent marker (e.g. site name, time, name of sampler etc.)

4.3.3 For metals, tick the box on the bottle label for either *filtered* or *total*, depending on whether samples for metals analysis will be filtered in the field.

4.3.4 Unscrew the cap, making sure not to touch the opening of the bottle with your fingers to avoid contaminating the sample. Put the cap upside-down on a clean surface where it won't pick up any contaminants.

4.3.5 If safe to do so (i.e. no crocodiles, steep banks, or fast water flow), fill the bottles directly from the water body being sampled; otherwise use the jug on the end of the pole to collect a water sample representative of the site.

4.3.6 Fully immerse the sample bottle or jug in the water and rinse at least 3 times before filling. For sample bottles containing preservatives (e.g. nutrients, VOC hydrocarbons), do not rinse before filling, use the jug to fill these sample bottles.

4.3.7 Make sure that you are standing downstream of where you are sampling so as not to contaminate the sample.

4.3.8 If using the jug, pour the water into each sample bottle.

4.3.9 Fill each bottle to the top leaving no headspace and screw on the cap.

4.3.10 For samples requiring field filtering (e.g. dissolved metals), draw some water (as per 3.4.4 above) into a syringe, put a filter on the end of the syringe, rinse the filter by pushing a few drops of the sample through onto the ground, then fill the bottle leaving no headspace. Depending on the size of the syringe, it may be necessary to draw several syringes-full of water to fill the sample bottle.

4.3.11 Put all the sample bottles back in the snap-lock bag and immediately place them in the esky with frozen ice-bricks.

4.3.12 Note that the procedure above is for the surface water bodies, ponds, and drains with direct access. Please refer to Sections 2.1.2 and 3.2 above for the slightly differing methods for the sumps without a pump, sumps with a pump, and the leachate ponds.

4.4 Groundwater sampling

4.4.1 Proceed to bore using map (Figure 2), coordinates (Table 2 and Table 3) and GPS.

4.4.2 Record on field sheets the date, time, site name/number, sampler's name, and field observations

4.4.3 Open bore cap using hand tools.

4.4.4 Lower the fox whistle or electronic dip meter and measure SWL.

4.4.5 Record the SWL and the Time on the Field Data Sheet.

If using Bailers:

4.4.6 Based on the SWL, calculate the volume of water in the bore requiring removal using this calculation:

$\pi r2 (D\text{-}SWL) \times 1000$
Where: r = the radius of the inner bore cap (in meters)
π = pi (3.14)
D = the total depth of the bore (in meters) taken from the bore reports
SWL = the Standing Water Level (distance from ground to water level – in meters)

4.4.7 Make sure bailer cord is securely attached to the bailer (each bore should have a separate bailer and cord).

4.4.8 Start bailing. Each bailer is just over 1 L when full, therefore assume each time you bail you are removing 1 L of water from the bore.

4.4.9 Lower the bailer inside the borehole slowly and gently until it is submerged.

4.4.10 Once the bailer fills, retrieve the bailer from the well slowly, in a steady, smooth motion and empty the bailer into the 20 L bucket.

4.4.11 Once the required amount of water is removed from the bore for purging, empty the 20 L bucket at least 5 m away from the bore to avoid contamination of the bore.

4.4.12 Collect water samples for laboratory analysis direct from bailer into sample bottle

4.4.13 Fill jug with sample water and in-situ readings (e.g. pH, Temperature, DO, Turbidity, and EC).

If using Low-Flow Pump:

4.4.14 Set up the pump, hose and compressor and attach power leads to car battery.

4.4.15 Lower pump into bore to the level where the bore casing is slotted (known from the bore report).

4.4.16 Lower dip meter back into bore so that SWL can be continuously measured during pumping – the pumping rate must be adjusted so that change in SWL is minimal i.e pumping rate = recharge rate.

4.4.17 Begin pumping and record the time pumping began on the Data Sheet.

4.4.18 Continue to pump and observe any reduction in SWL to match pumping rate with recharge rate.

4.4.19 After about 5 minutes of pumping take a photo of the water colour and make any observations such as colour, sediment, odour or contamination etc

4.4.20 Set up flow-through cell and insert water quality meters (pH, EC, ORP, DO).

4.4.21 Every 5 min record the time, SWL, Temperature, flow rate, pH, EC, ORP, DO, Turbidity and any water colour, odour, signs of hydrocarbon sheen or other contamination.

4.4.22 Continue pumping until three consecutive readings stabilise within 5% of each other. Record all readings on the Field Data Sheet.

4.4.23 Once a stable chemistry is reached (usually after about 30 min of pumping depending on the bore), record the final time, SWL and water quality parameters and collect water samples for laboratory analysis direct into sample bottles from the hose.

4.1 Cleaning of field equipment

4.1.1 After sampling each surface water / leachate site or groundwater bore, rinse all sampling equipment (e.g. jugs, groundwater pump hoses) with the pre-mixed Decon 90 solution, followed by deionised water.

4.1.2 For the groundwater pump hose this means placing pump into the 20 L bucket with decon and then deionised water to flush the hose. Also, the external surface of the hose must be rinsed with decon and deionised water.

4.1.3 Dispose of used filters, syringes, and gloves in the garbage bag.

4.1 Collection of field blanks, split samples and duplicates

4.1.1 The QA/QC samples required are listed in Section 3.4 above.

4.1.2 To collect a field blank, simply follow the steps outlined above using de-ionised water instead of water from the site / bore being sampled.

4.1.3 For split / triplicate samples and duplicates, collect extra bottle sets using the same surface water / groundwater sampling methods as per above steps.

4.1.4 Ensure to note collection of these samples on the Field Data Sheet for that site / bore as the site location mustn't be recorded on the sample bottles.

4.2 Sample dispatch

4.2.1 Fill out the COC.

4.2.2 Prepare a small esky containing the split samples for dropping to separate laboratory.

4.2.3 Deliver samples direct to laboratory shop fronts.

4.2.4 Note that all samples must be delivered to the laboratories to allow for analysis to be undertaken within holding times (see Table 13). The shortest holding time is two days for BOD, nitrate, nitrite and phosphorus. In order to allow samples to be delivered to the interstate laboratories and meet this holding time, samples with these parameters (i.e. all quarterly and annual samples) will need to be delivered to the Darwin ALS / Eurofins mgt shopfront by 3 pm each day and not on a Friday, Saturday or Sunday. As such, sampling will need to start very early (7 am) and be completed in four days (Mon/Tues/Wed/Thurs). If sampling is not completed on Thursday, it will need to be finished the following Monday. The shortest holding time for monthly samples is 14 days, therefore sample delivery to the laboratories by 3 pm is not critical but this will be achieved if possible.

4.3 Data management

4.3.1 At the end of each day, all Field Data Sheets must be scanned and saved, and all photographs downloaded, saved, and labelled according to the relevant site name.

4.3.2 Once the Sample Receipt Notification (SRN) is received from the Labs, notify the Waste Services Manager of the expected due date for sample analysis results. Also check the SRN for any mistakes, missing analysis etc and inform labs immediately of any issues.

4.3.3 Send all scanned Field Data Sheets and photographs to the Waste Services Manager on completion of the monthly sampling round.

4.3.4 Send all lab results to Waste Services Manager immediately upon receipt.

5 Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BTEXN	Benzene, Toluene, Ethyl benzene, Xylenes, and Naphthalene
COA	Certificate of Analysis
COC	Chain of Custody form
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPL	Environment Protection Licence
LOR	Limit of Reporting
N.A.T.A	National Association of Testing Authorities
NT EPA	Northern Territory Environment Protection Authority
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated biphenyls
PPE	Personal Protective Equipment
QA / QC	Quality Assurance / Quality Control
RDX	Cyclotrimethyne trinitramine
SOP	Standard Operating Procedure
SRN	Sample Receipt Notification
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TNT	Trinitrotoluene
TOC	Total Organic Carbon
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbons
VFA	Volatile acids as acetic acid

6 References

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NT EPA 2011, *Environment Protection Licence EPL12-09*, Issued 1 March 2011, Expires 1 July 2016, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

NT EPA 2013, *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998), Standards Australia, New South Wales.

Sundaram, B., Feitz, A., Caritat, P. de, Plazinska, A., Brodie, R., Coram, J. and Ransley, T., 2009. *Groundwater Sampling and Analysis – A Field Guide*. Geoscience Australia, Record 2009/27, Commonwealth Government, Canberra.

ANZECC & AMRCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

ANZECC & AMRCANZ 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

Appendix A – Surface Water / Leachate Field Data Sheet

EcOz Environmental Services

Surface Water Field Data Sheet

PROJECT:	DATE and TIME:
SITE NUMBER / NAME:	
SAMPLERS NAME:	PHOTO NOs:
EASTING:	NORTHING:

GENERAL OBSERVATIONS			
WATER COLOUR		PRESENCE OF AQUATIC FAUNA	
ODOUR		AQUATIC PLANTS	
SURFACE SCUM/ALGAE		EROSION	
RIPARIAN CONDITION		GROSS POLLUTANTS	
WATER CONDITIONS			
APPROX DEPTH OF WATER (m)		WATER FLOW (m/sec)	

WEATHER CONDITIONS

Cloud cover/ precipitation/ wind conditions:

FIELD SAMPLES

Parameter	Unit	Result	Meter Used	Date of calibration
pH				
Temperature				
E.C				
TDS				
Salinity				
D.O				
ORP				
Turbidity				

LABORATORY SAMPLES

Analytes Requested	Containers Used	QA/QC Samples Collected (circle)
		Duplicate Split Blank

Any other comments or special procedures (see over):

Appendix B – Groundwater Field Data Sheet

EcOz Environmental Services

Groundwater Sampling Data Sheet

Site/Project:	
Sample Date:	
Bore Name:	
Sampled By:	
Bore Head Condition:	
Total Depth (mbgl):	
Screen Intervals (mbgl):	
Pump Depth:	

SWL Initial (m below top of casing):				
Casing Height (m above ground):				
SWL Initial (m below ground level):				
Casing:		**Colour at Start:**	**Odour:**	**Equip?**
PVC			Nil	Y N
Steel		**Colour at End:**	H_2S	psi
Other			Other:	L/s
Comments:				

Time started Pumping/Purging:										
Time										24hr
EC										µs/cm
pH										
Temp										ºC
Turbidity										NTU
Salinity										ppt
TDS										g/L
ORP										mV
D.O.										%sat
SWL										mbtoc
Flow Rate										L/min

Time										24hr
EC										µs/cm
pH										
Temp										ºC
Turbidity										NTU
Salinity										ppt
TDS										g/L
ORP										mV
D.O.										%sat
SWL										mtoc
Flow Rate										L/min

Time Lab Samples Collected:

Comments:

Appendix C – Laboratory Chain of Custody Form

CHAIN OF CUSTODY

ALS Environmental

ALS Laboratory: please tick →

❑ ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com

❑ BRISBANE 32 Shand Street StaffordQLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com

❑ GLADSTONE 46 Callemondah Drive ClintonQLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com

❑MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com

❑MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com

❑MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com

❑ NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com

❑ NOWRA 4/13 Geary Place NorthNowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com

❑ PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com

❑SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com

❑TOWNSVILLE 14-15 Desma Court Bohle QLD4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com

❑WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: EcOz Environmental	**TURNAROUND REQUIREMENTS :** (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)	☐ Standard TAT **(List due date):**	**FOR LABORATORY USE ONLY (Circle)**
OFFICE: Darwin		☐ Non Standard or urgent TAT **(List due date):**	Custody Seal Intact? Yes No N/A
PROJECT: EZ20036 Shoal Bay Water Monitoring	**ALS QUOTE NO.:** SY/328/16B	**COC SEQUENCE NUMBER (Circle)**	Free ice / frozen ice bricks present upon receipt? Yes No N/A
ORDER NUMBER:		COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: °C
PROJECT MANAGER: Helen Dwyer	**CONTACT PH: 08 8981 1100**	OF: 1 2 3 4 5 6 7	Other comment:

SAMPLER:	**SAMPLER MOBILE:**	**RELINQUISHED BY:**	**RECEIVED BY:**	**RELINQUISHED BY:**	**RECEIVED BY:**
COC emailed to ALS? (YES / NO)	**EDD FORMAT (or default):**				
Email Reports to: bill.dwyer@ecpz.com.au; andrew.lewis@ecoz.com.au ; helen.dwyer@ecoz.com.au;		DATE/TIME:	DATE/TIME:	DATE/TIME:	DATE/TIME:
Email Invoice to: ecoz@ecoz.com.au; helen.dwyer@ecoz.com.au					

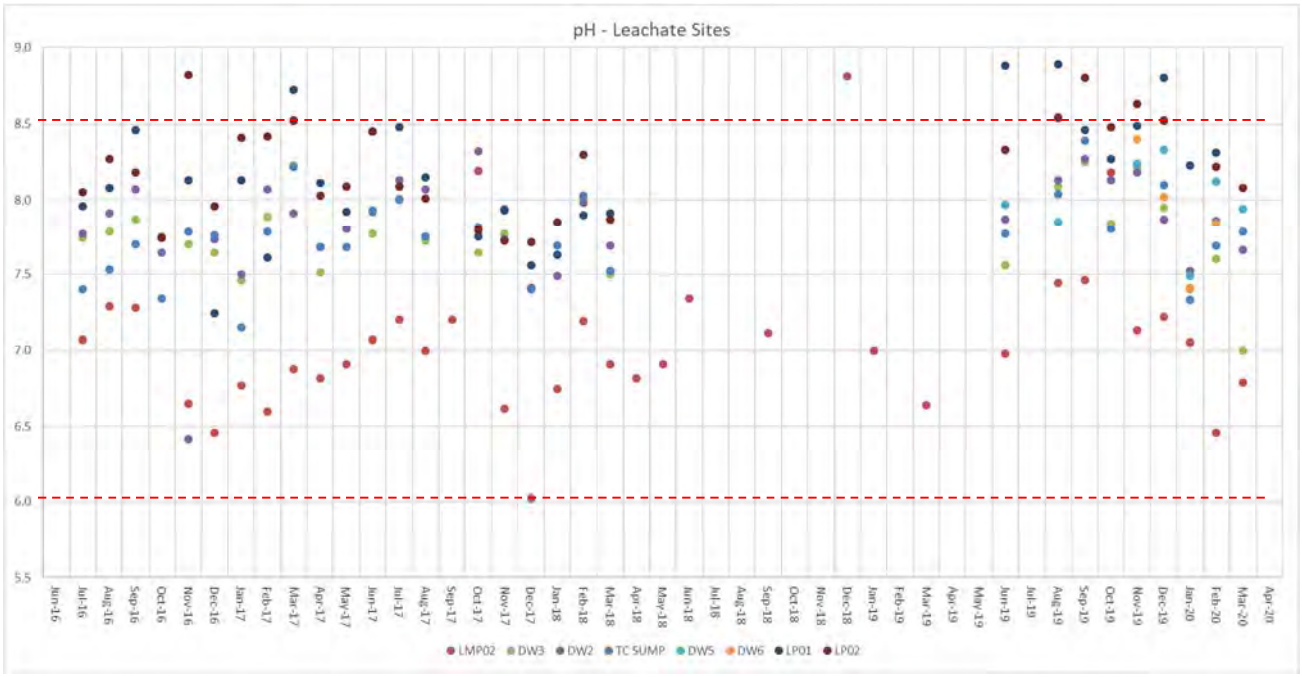
COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).													Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS														
				TOTAL															

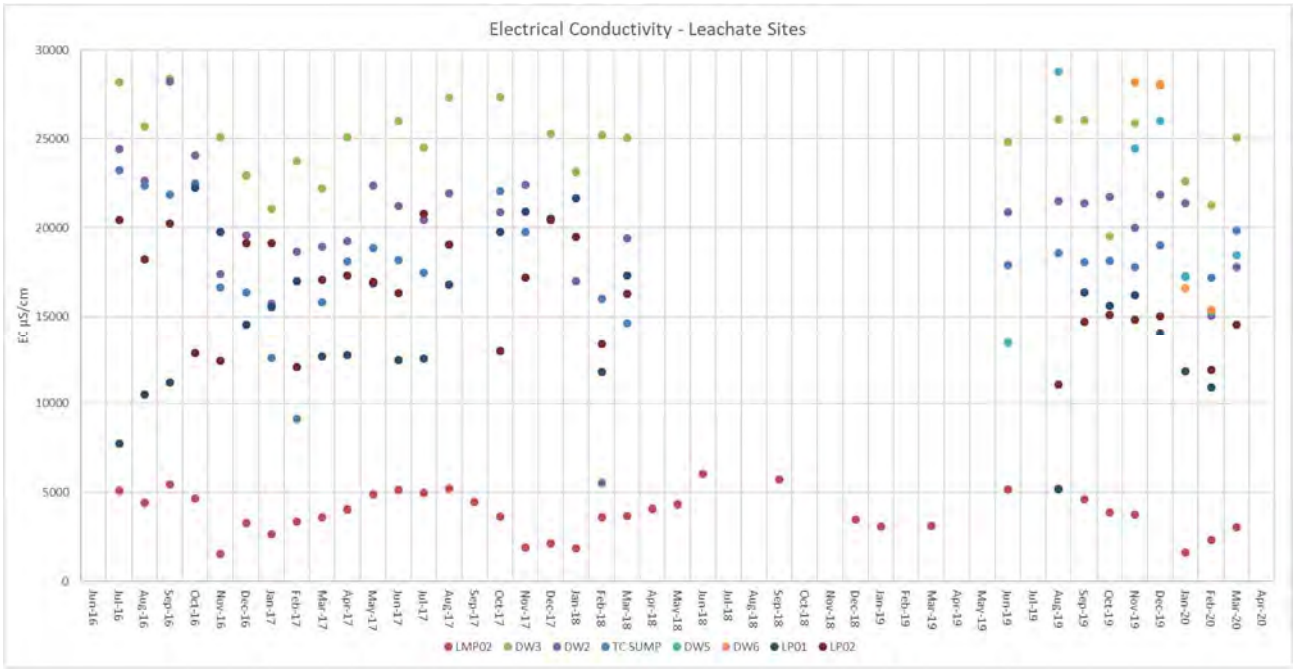
Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

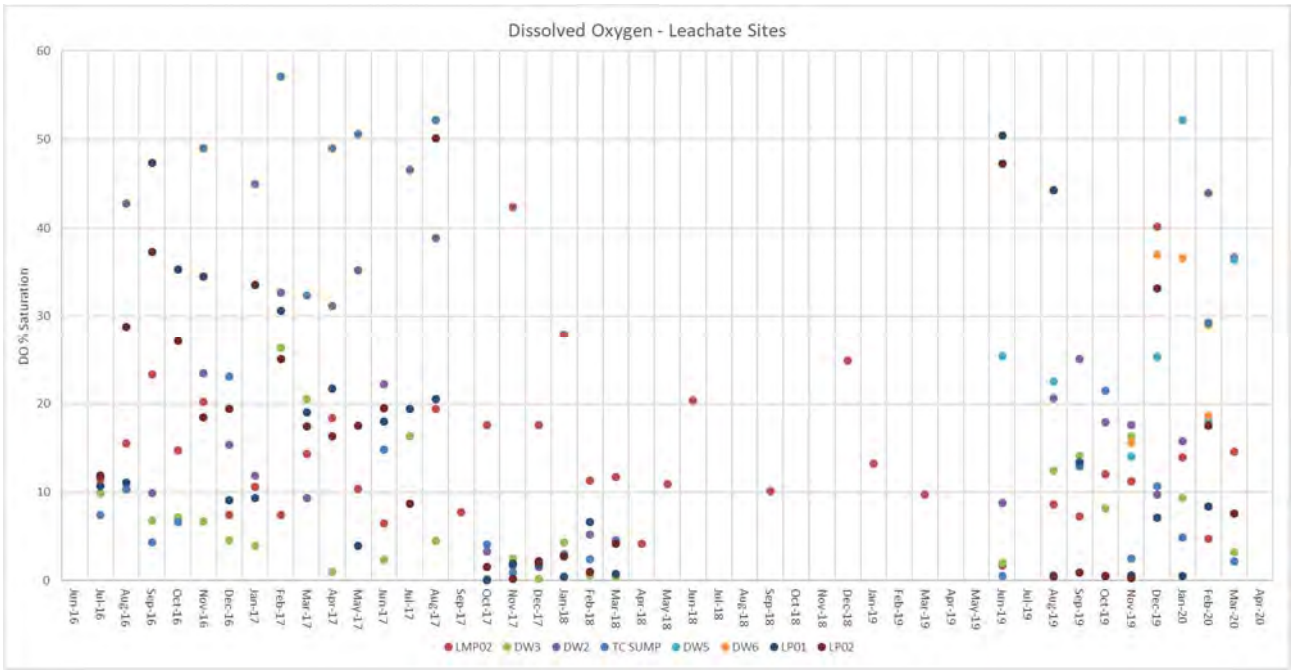
APPENDIX B WATER QUALITY TREND ANALYSIS GRAPHS

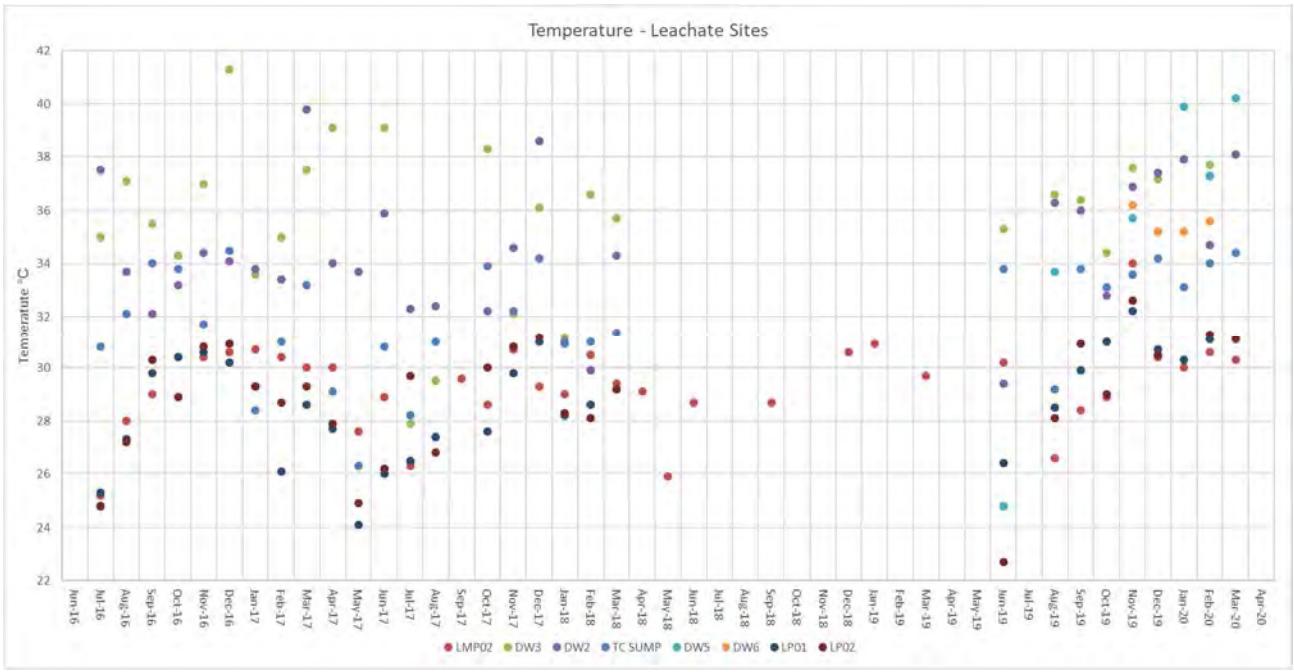
Graphs of leachate sites measurements between July 2016 and March 2020.

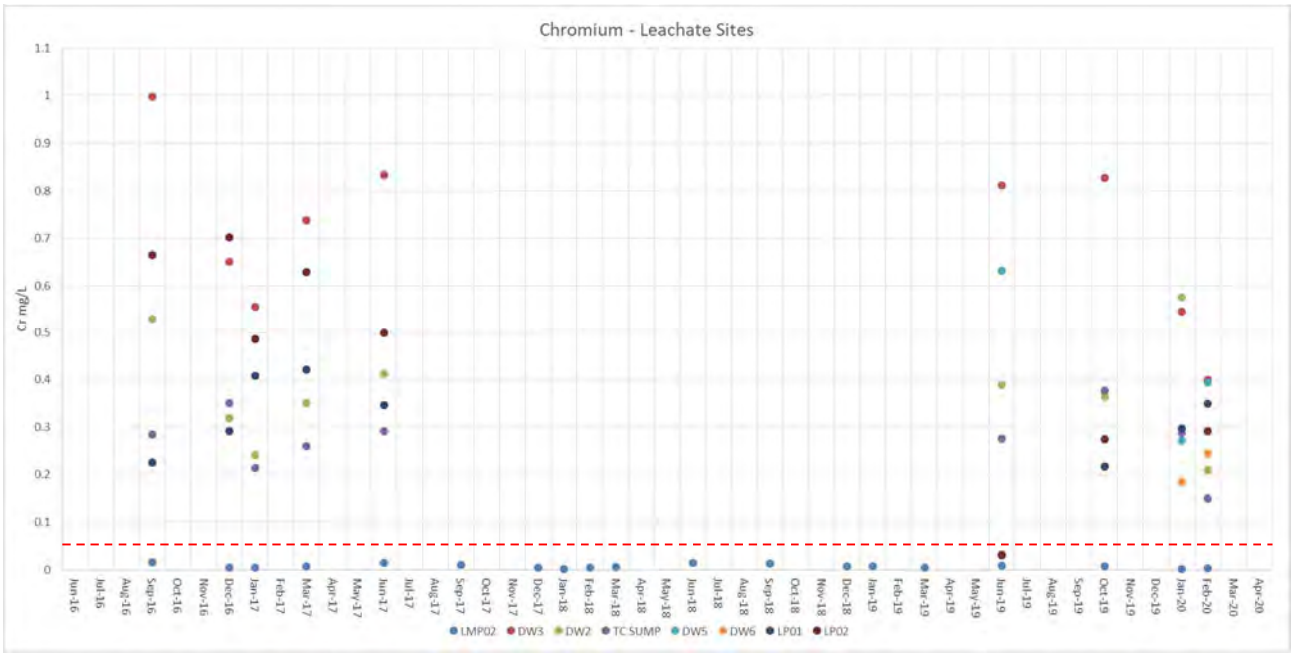


Darwin Harbour water quality objective upper and lower limits shown by red dashed lines.

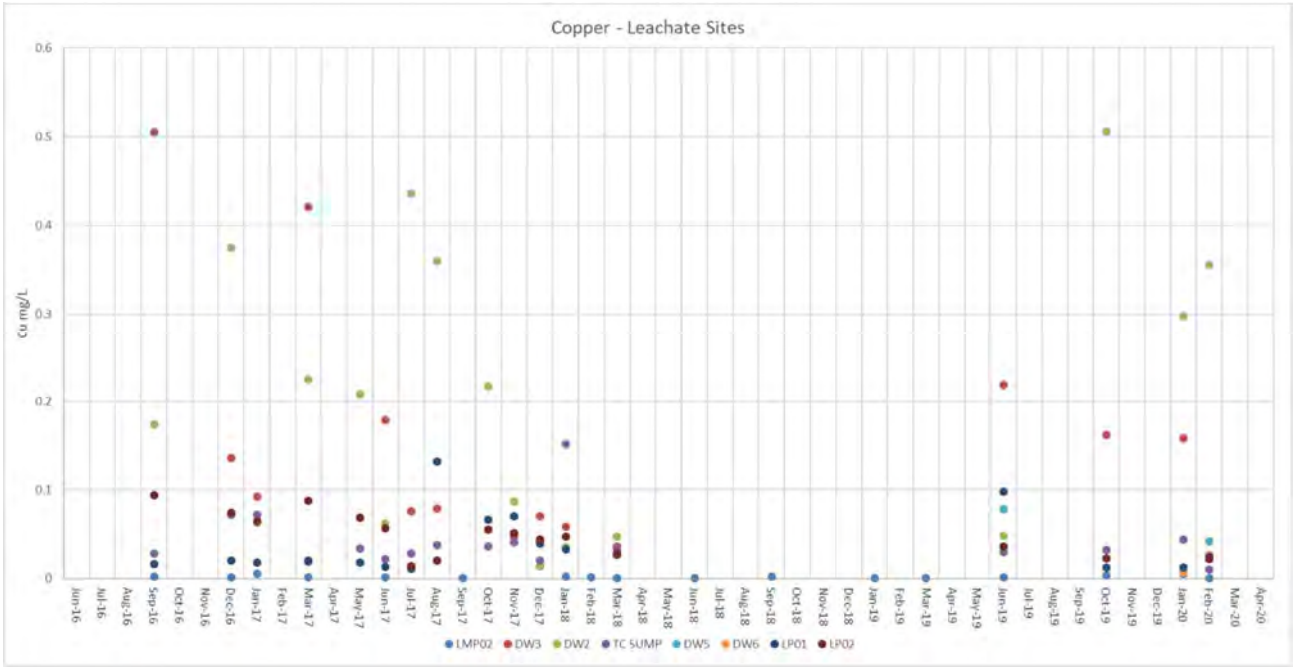



Dissolved Oxygen - Leachate Sites
DO % Saturation
60
50
40
30
20
10
0
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
LMP02
DW3
DW2
TC SUMP
DW5
DW6
LP01
LP02

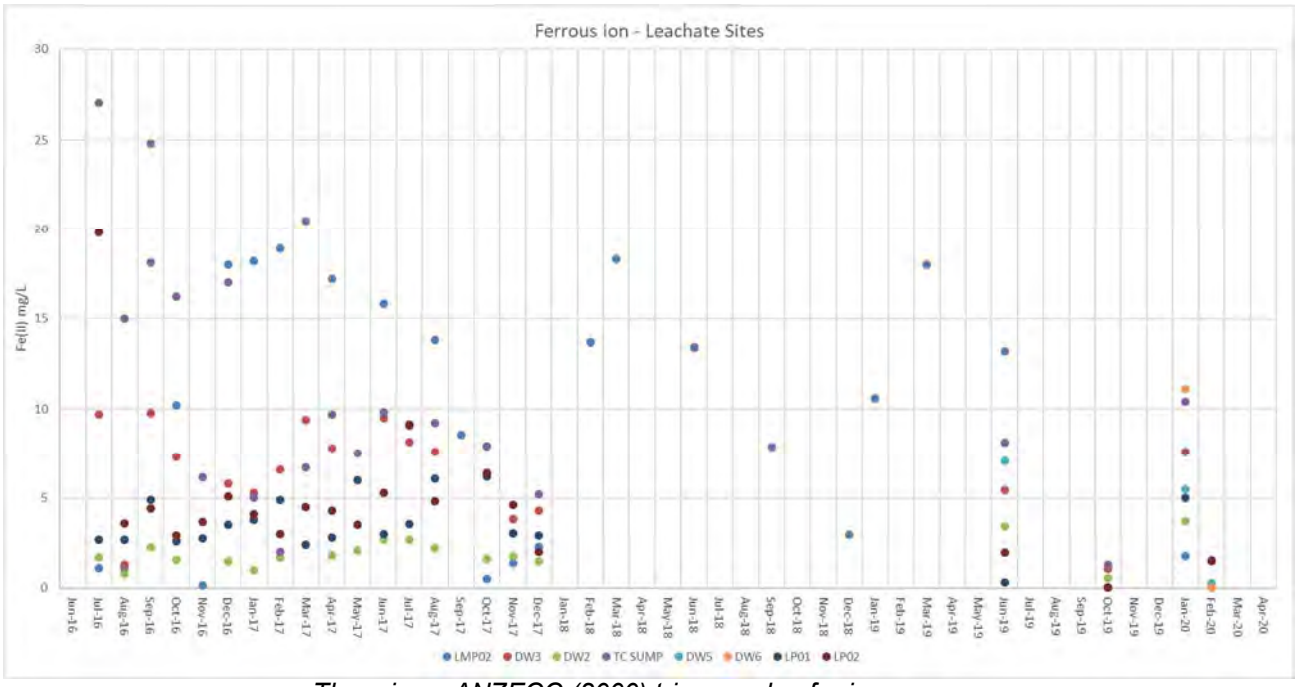

Temperature - Leachate Sites
Temperatute °C
42
40
38
36
34
32
30
28
26
24
22
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
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Jun-19
Jul-19
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Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
LMP02
DW3
DW2
TC SUMP
DW5
DW6
LP01
LP02



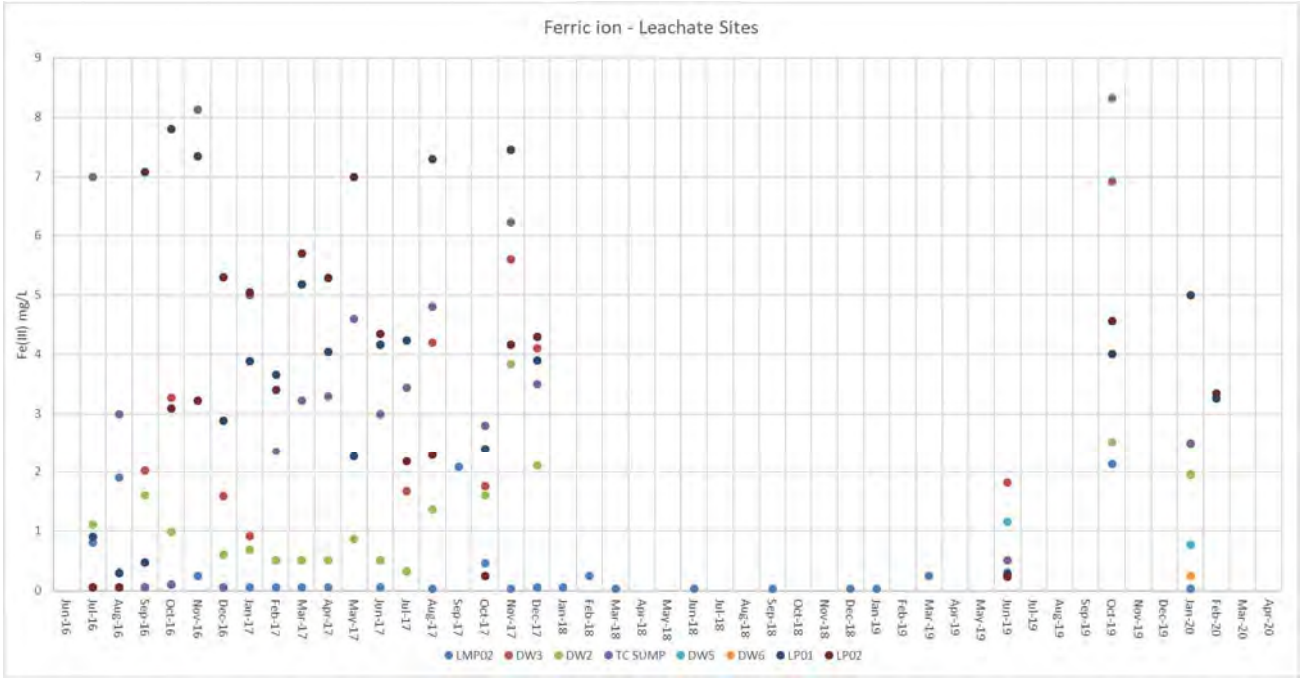
ANZECC (2000) trigger value for 90% species protection in marine water for chromium (III) is used (i.e. 0.049 mg/L) given when concentrations of chromium (III) and chromium (VI) are above the LOR, all the chromium exists as chromium (III).



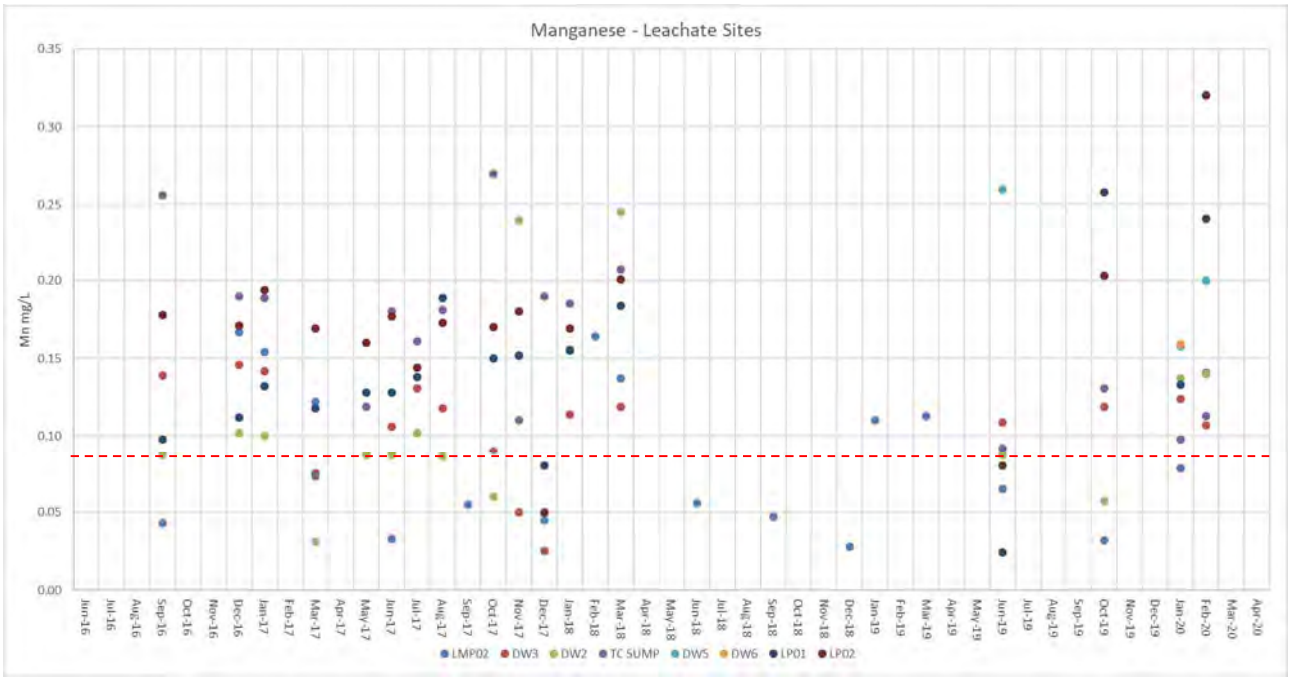
ANZECC (2000) trigger value for 90% species protection in marine water is 0.003 mg/L and too low to be shown on the graph; all concentrations (except for LMP02) are above the trigger value.



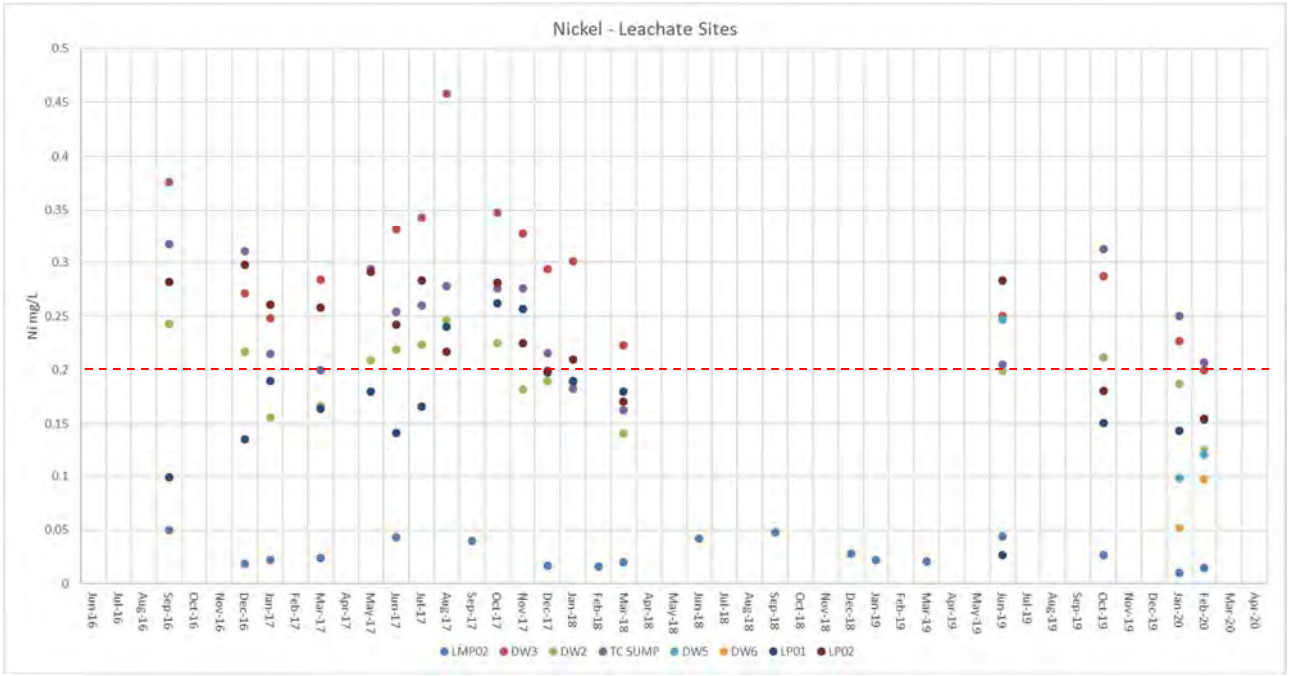
There is no ANZECC (2000) trigger value for iron.



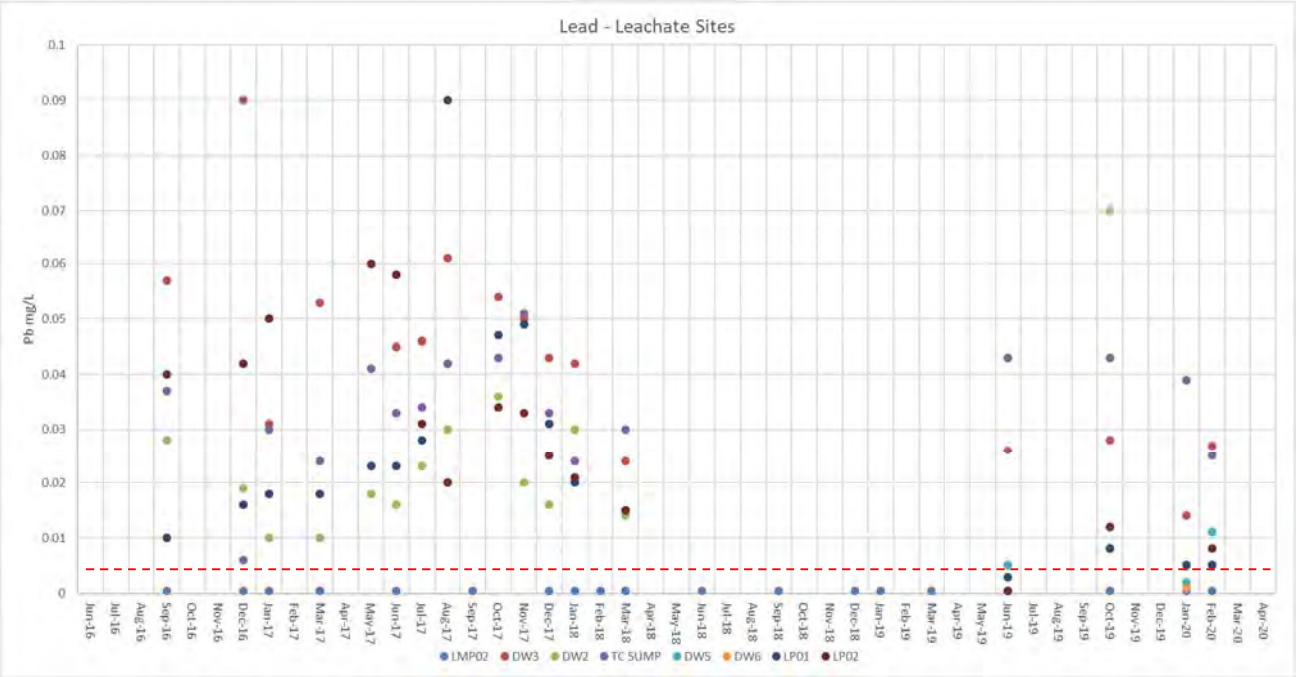
There is no ANZECC (2000) trigger value for iron.



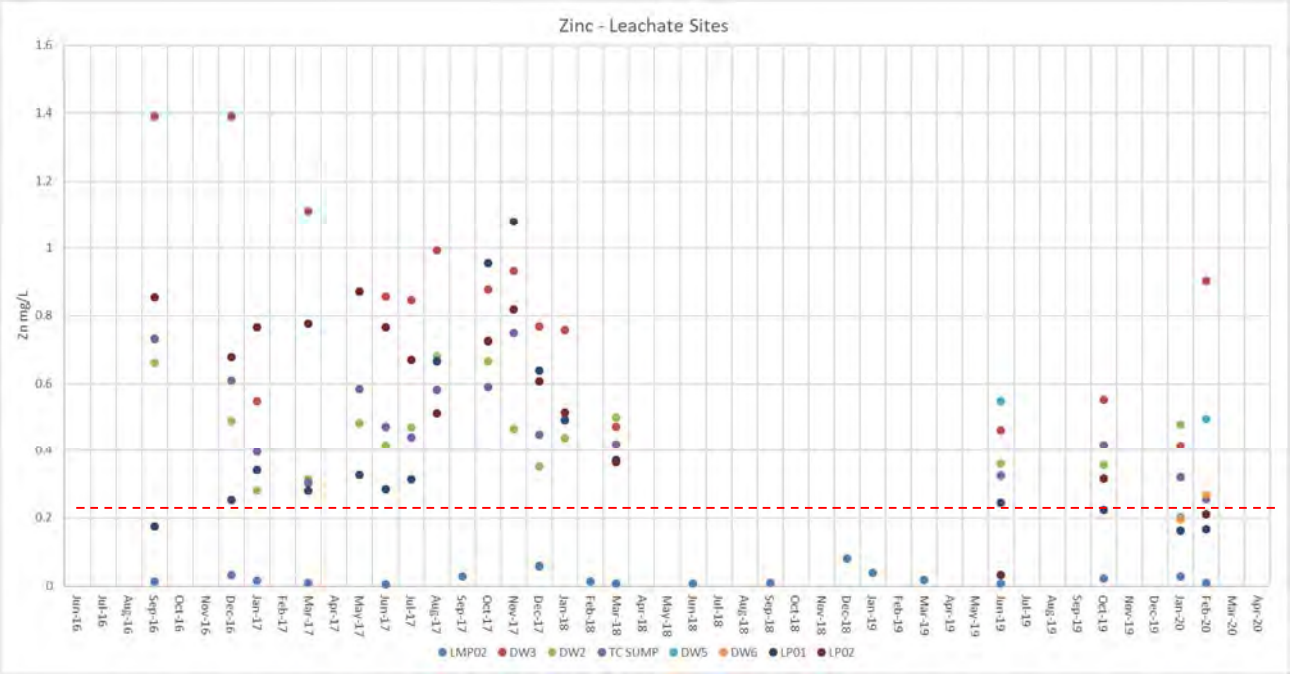
ANZECC (2000) 'low reliability' trigger value in marine water shown by red dashed line i.e. 0.08 mg/L. This value is based on limited data and should be considered as indicative only. No species protection level is indicated.



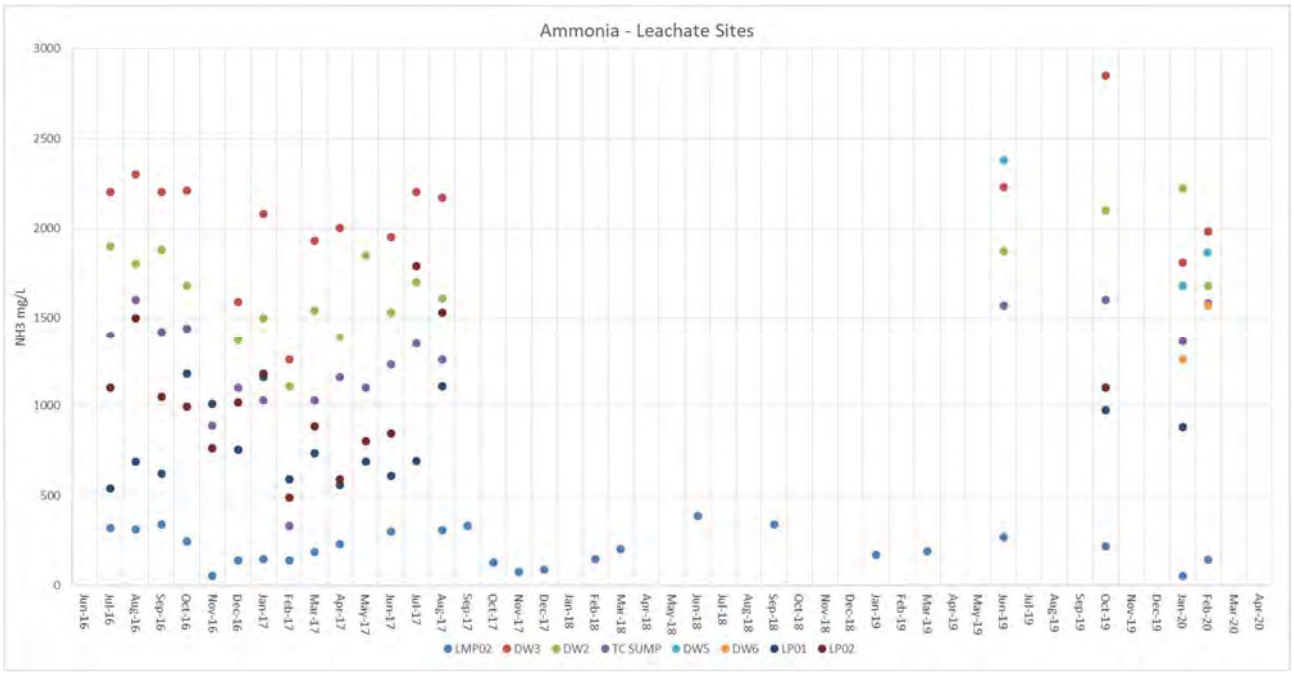
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.2 mg/L.



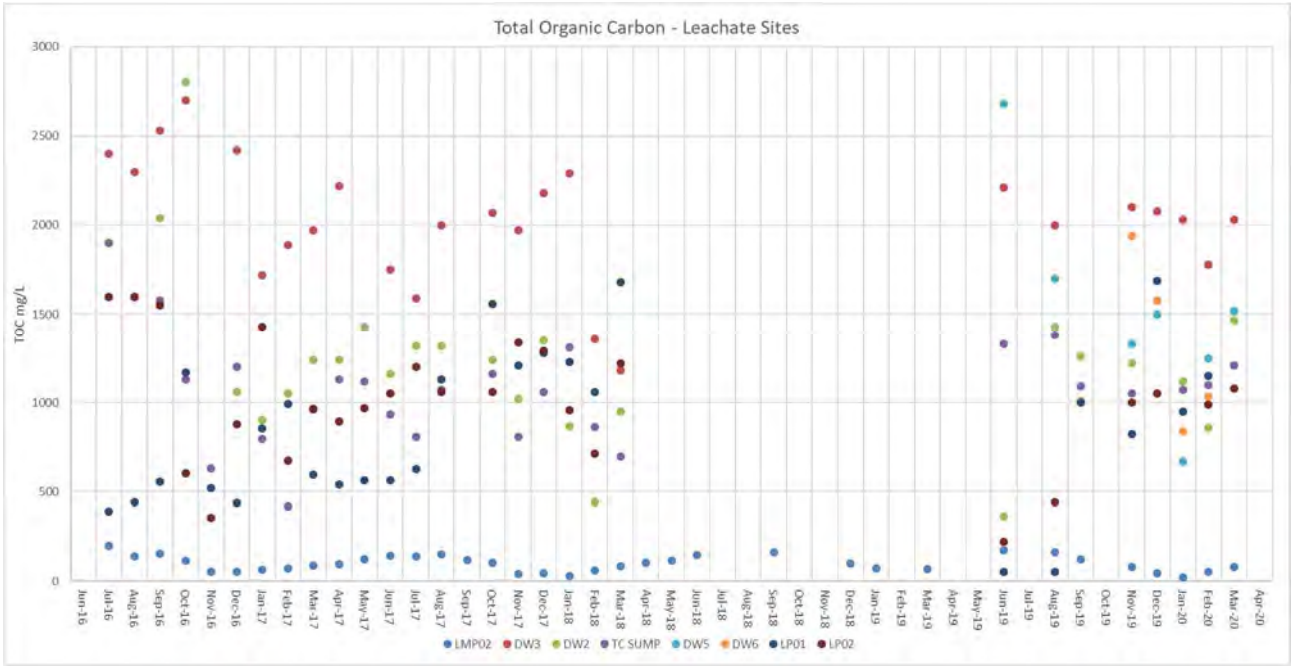
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.0066 mg/L.



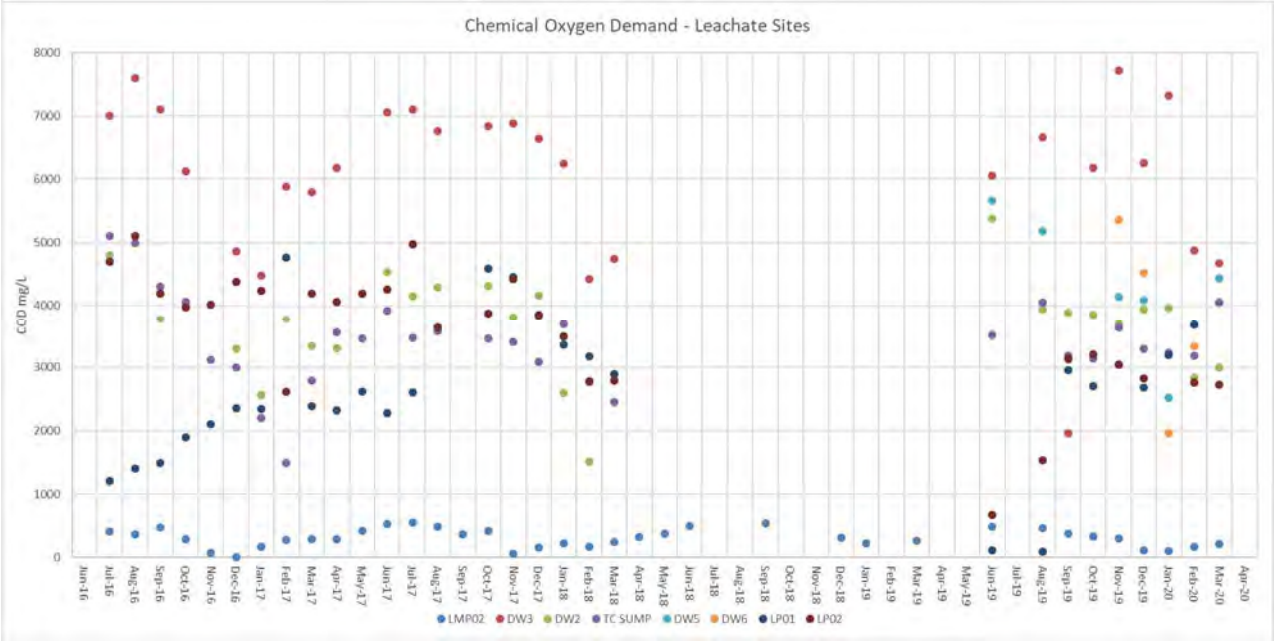
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.023 mg/L.



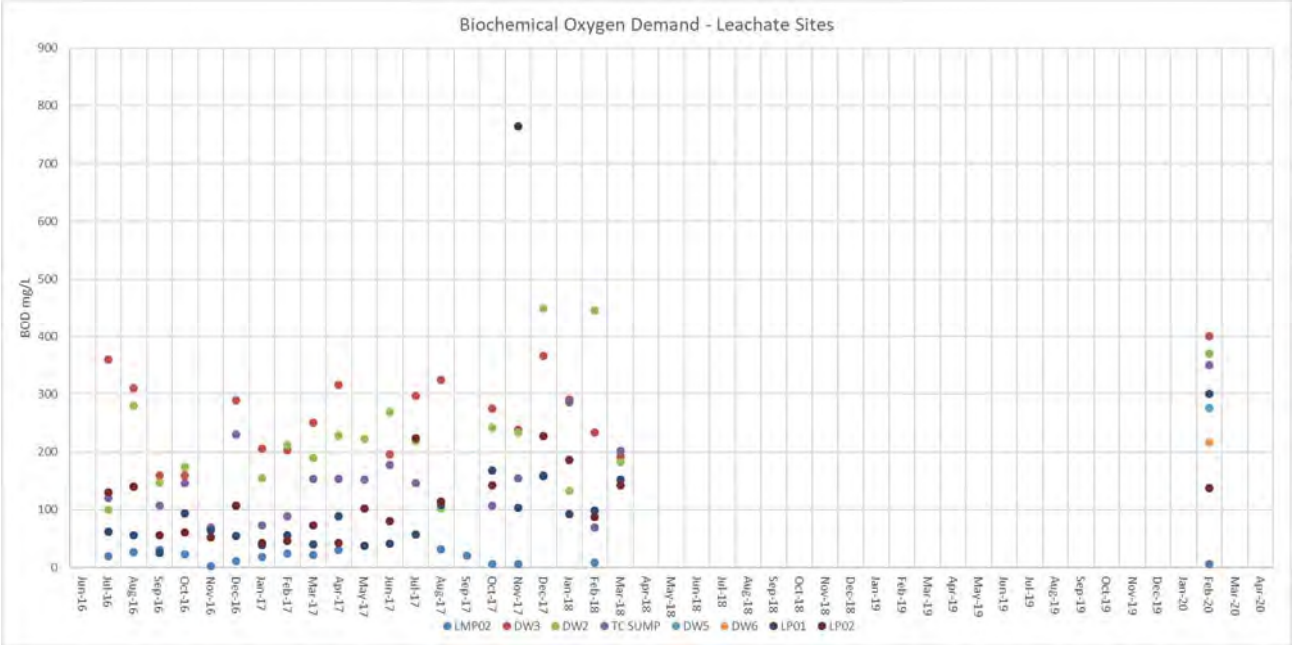
ANZECC (2000) trigger value for 90% species protection in marine water is 1.2 mg/L and too low to be shown on the graph; all concentrations are above the trigger value.



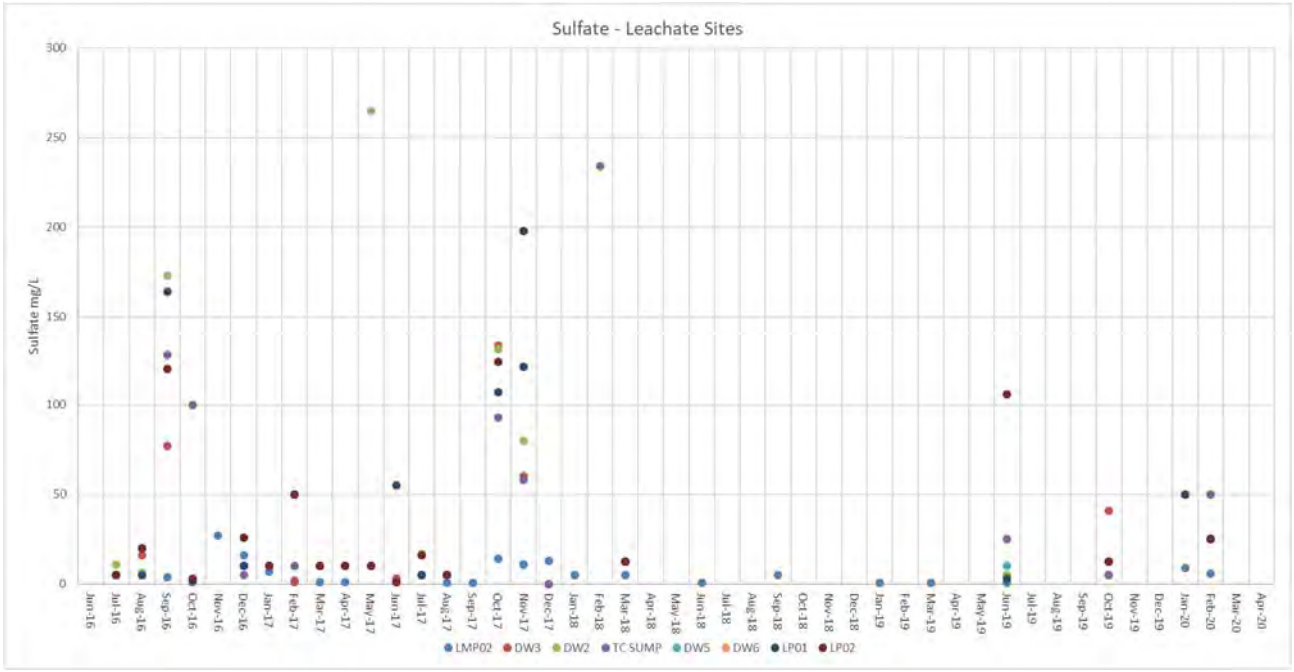
There is no ANZECC (2000) guideline value for TOC.



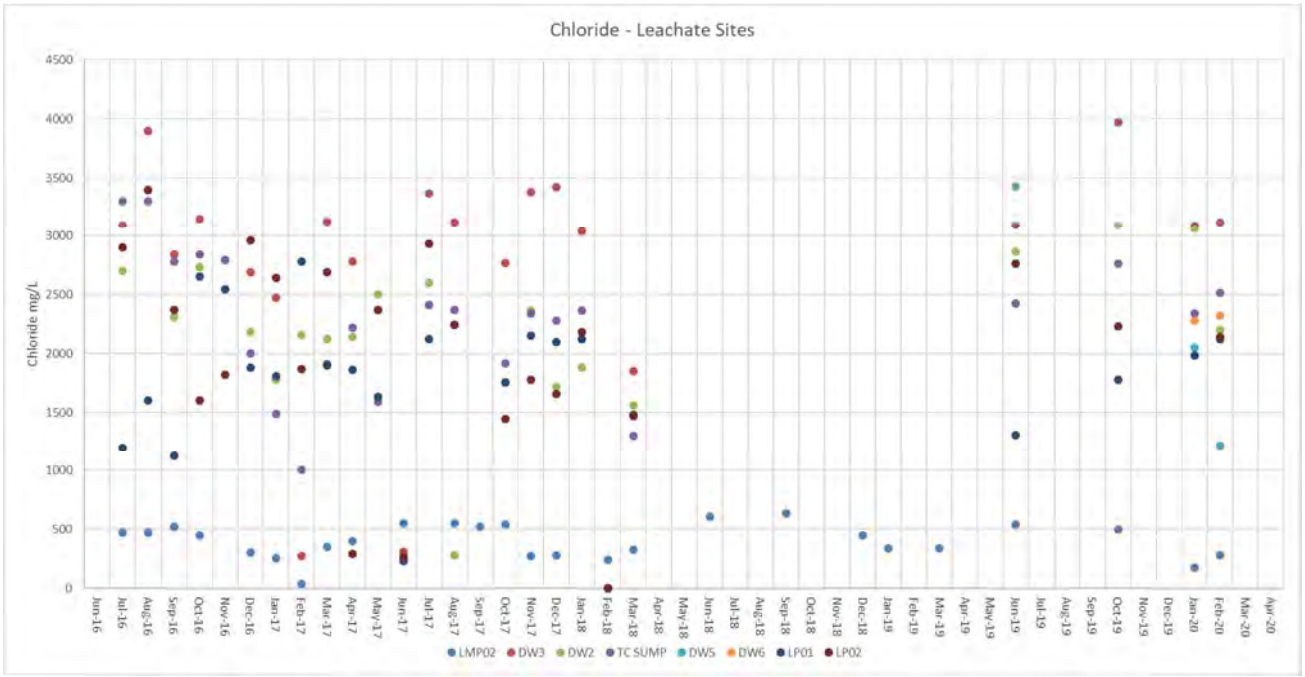
There is no ANZECC (2000) guideline value for COD.



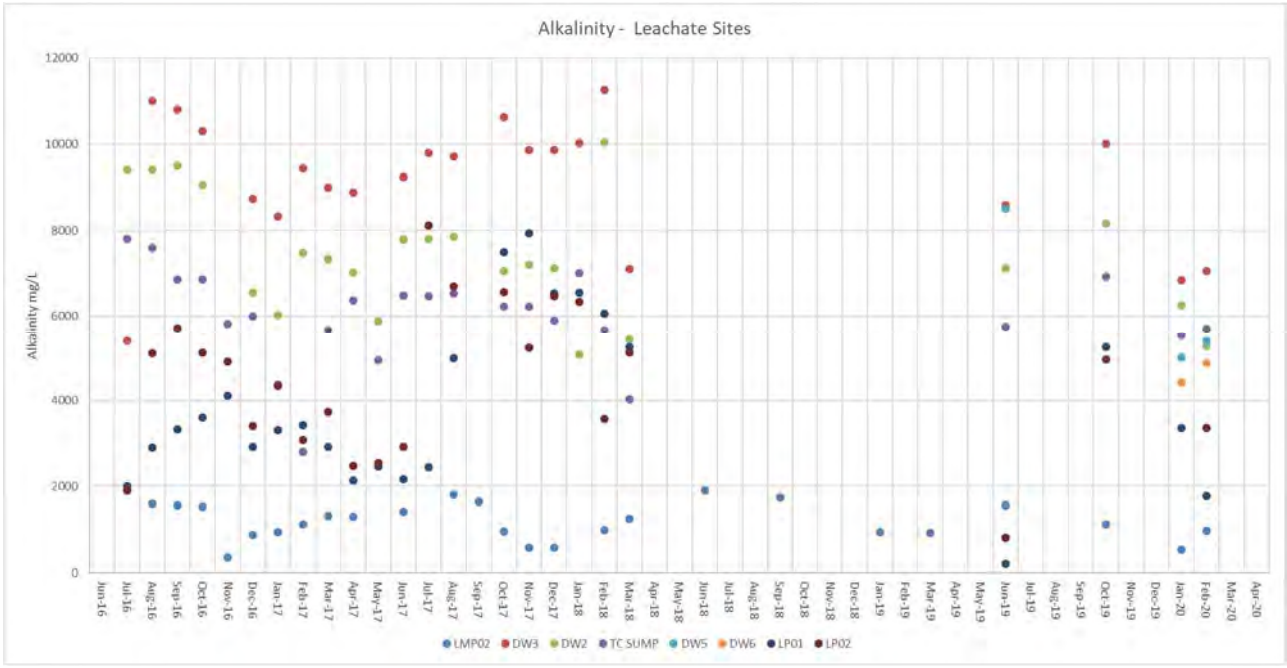
There is no ANZECC (2000) guideline value for BOD.



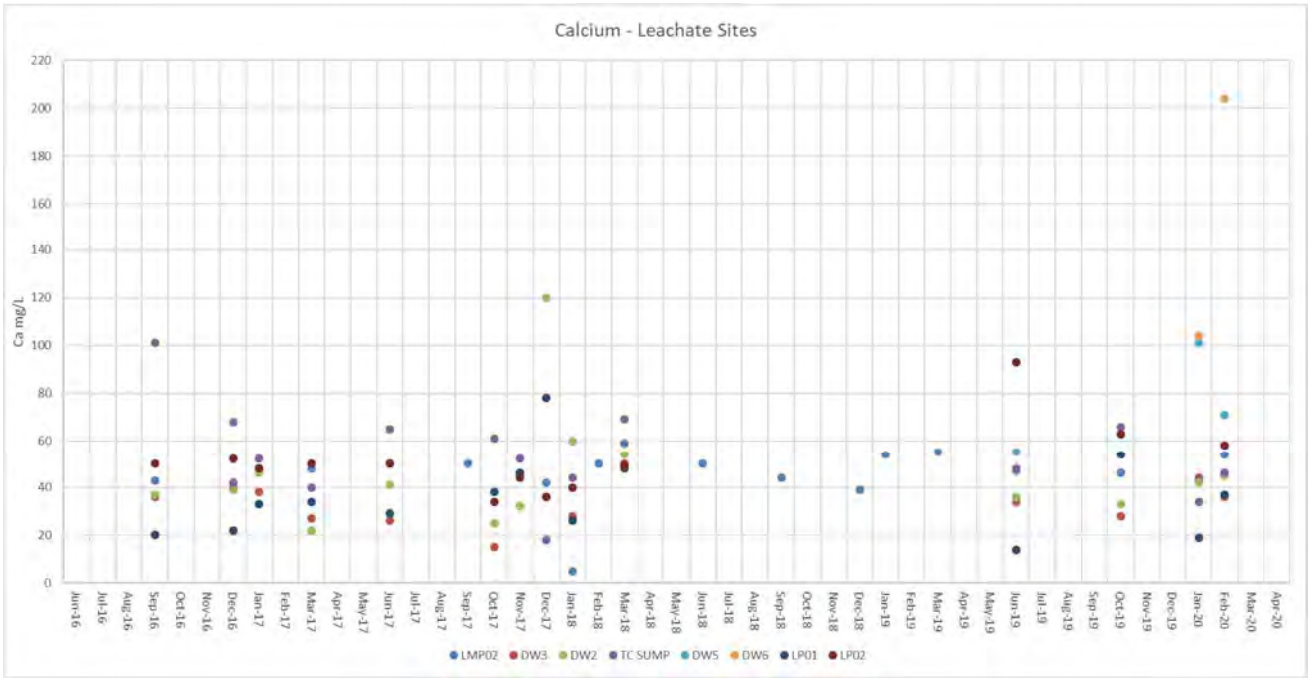
There are no ANZECC (2000) guideline values for anions and cations.



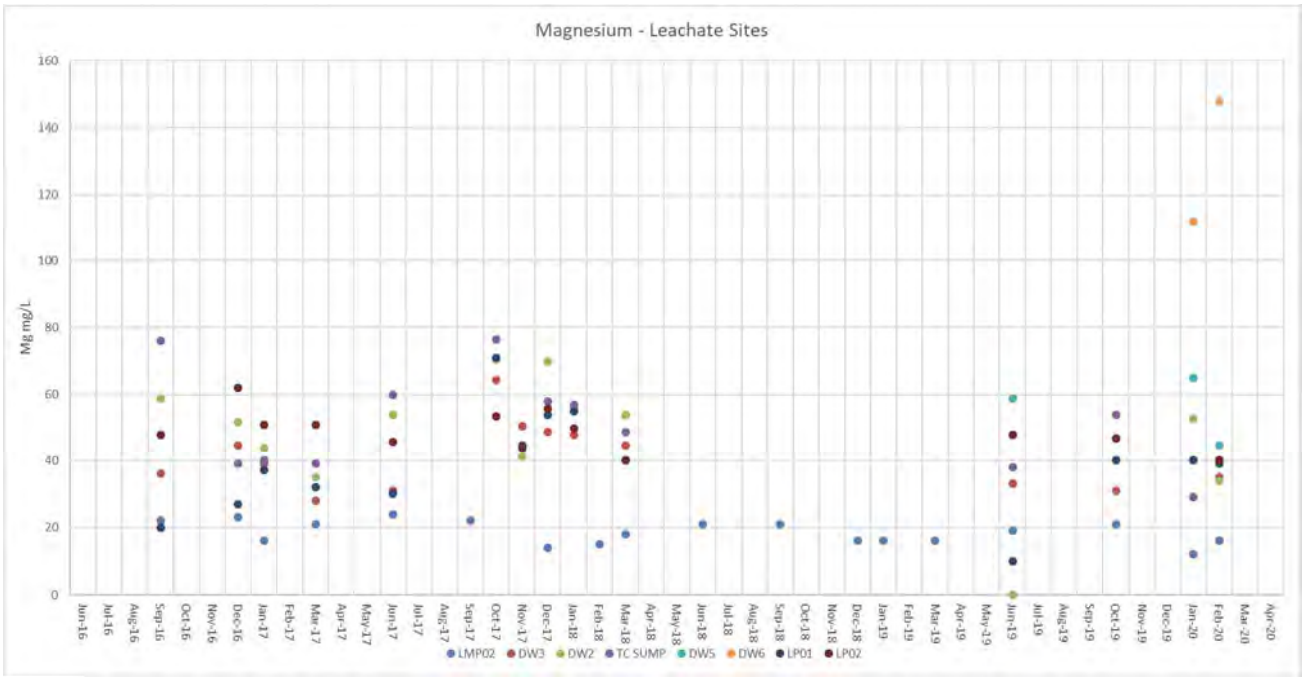
There are no ANZECC (2000) guideline values for anions and cations.



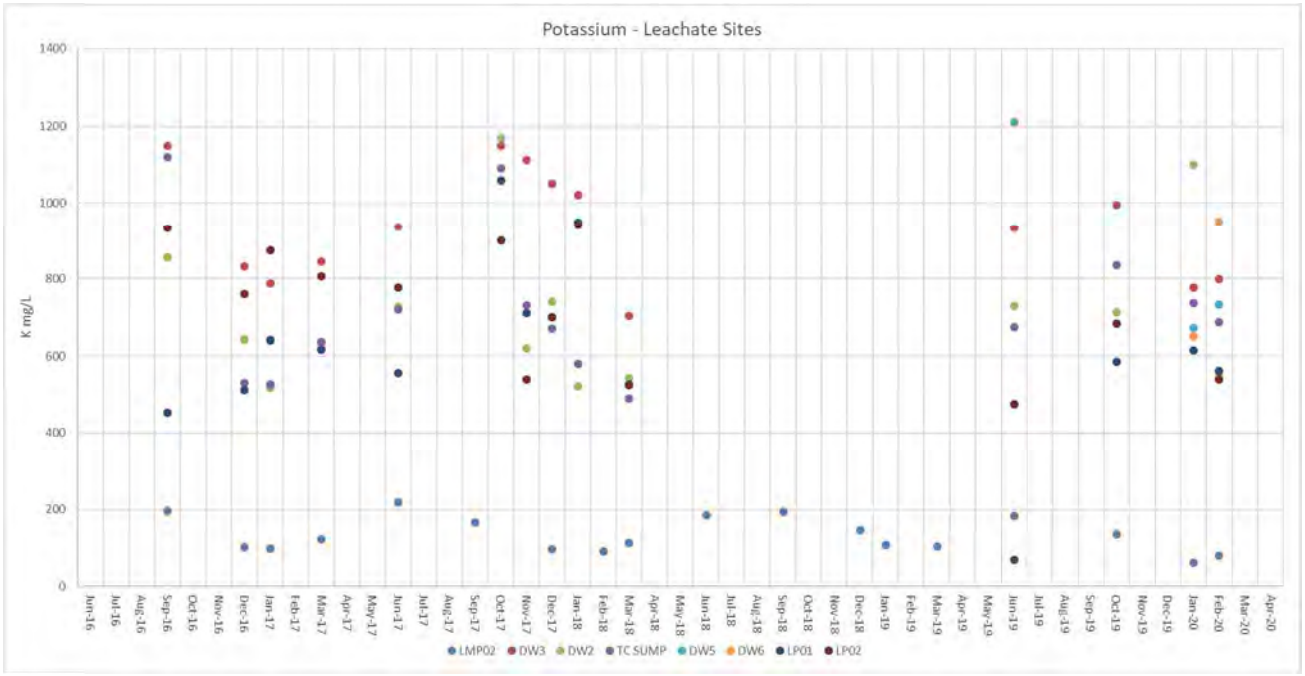
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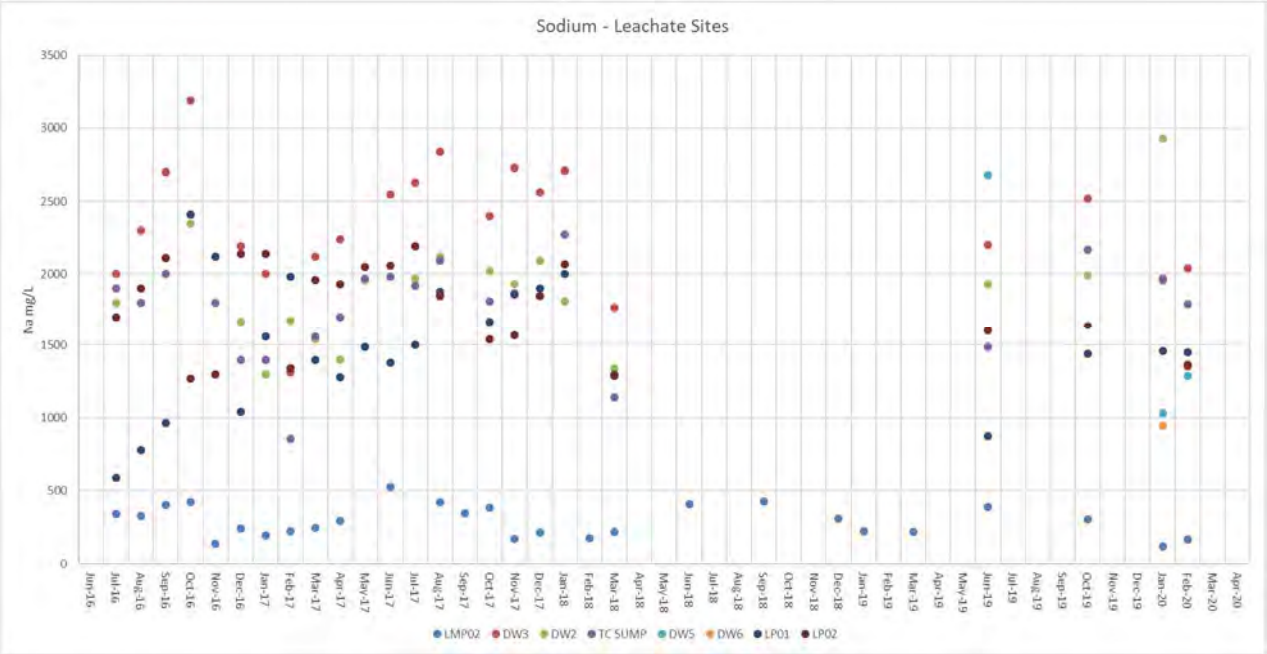
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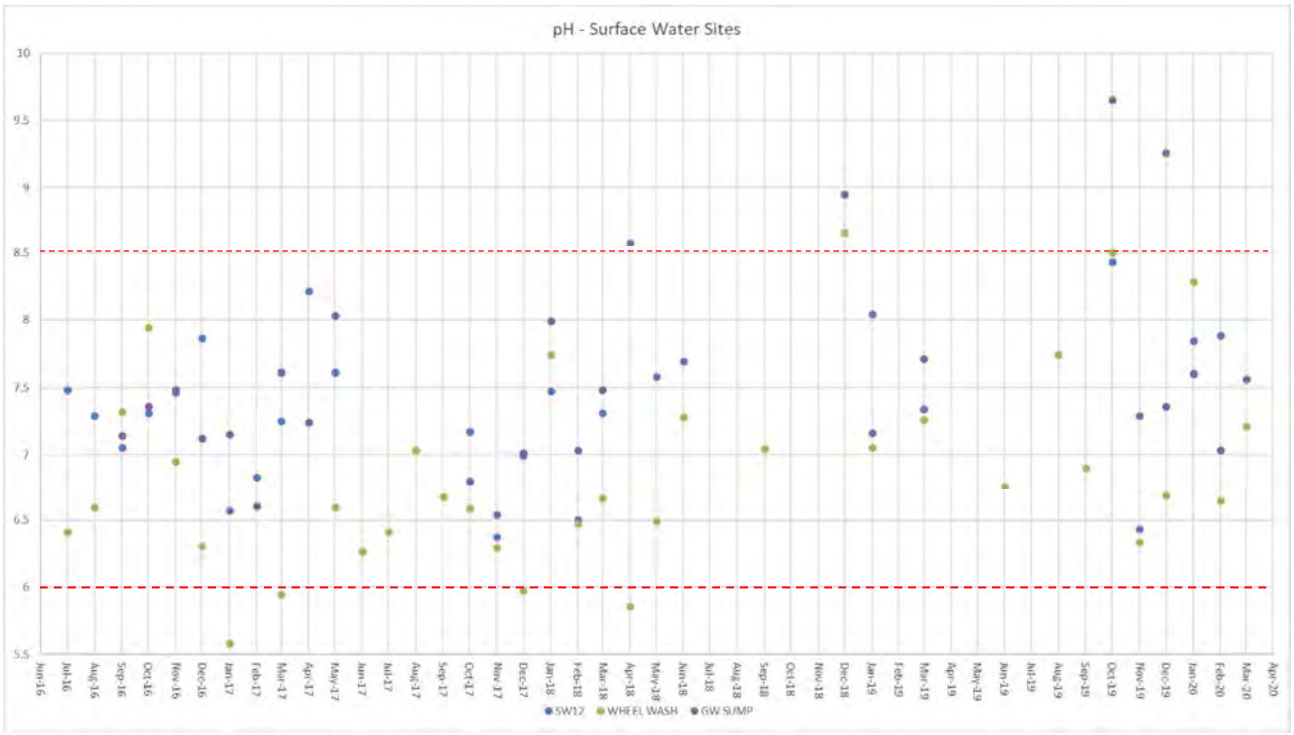


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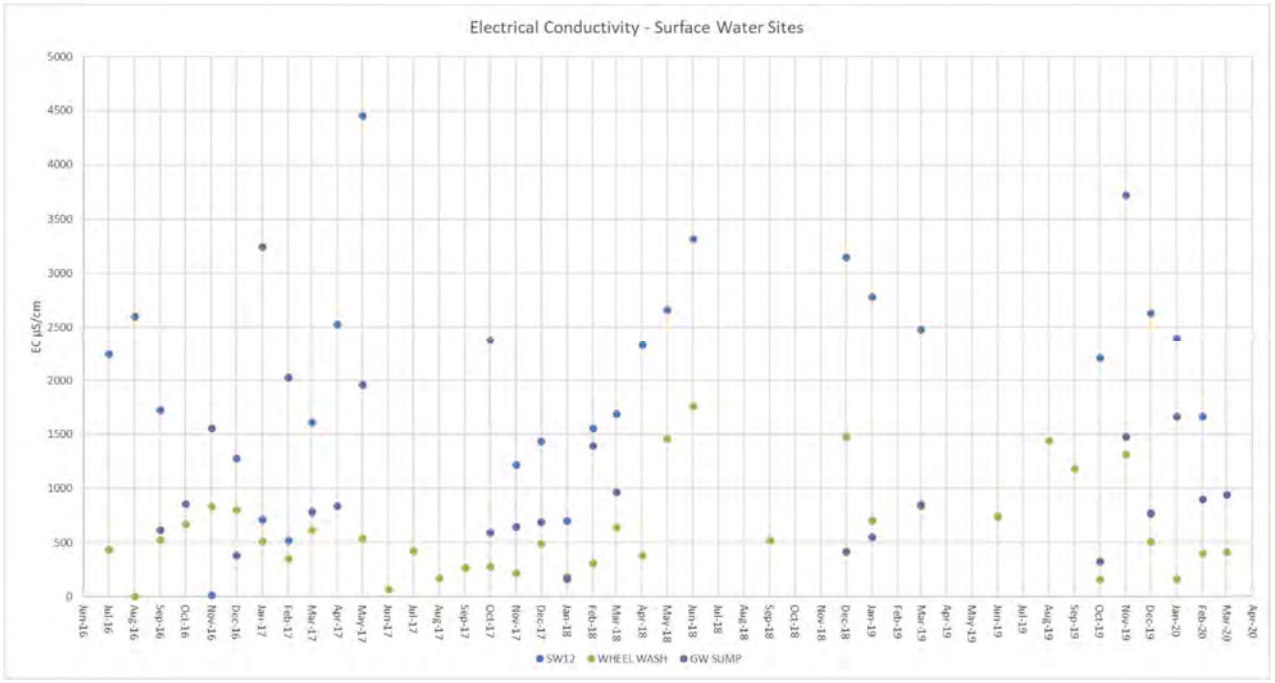


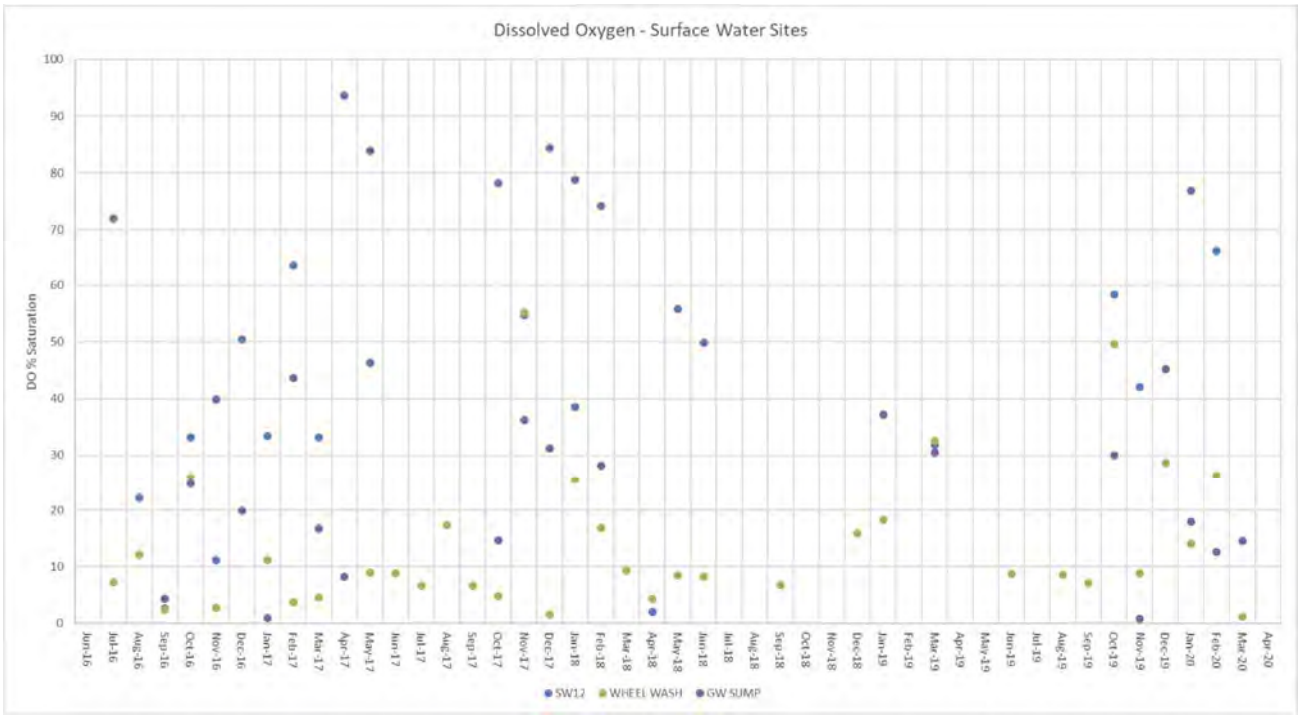
There are no ANZECC (2000) guideline values for anions and cations.

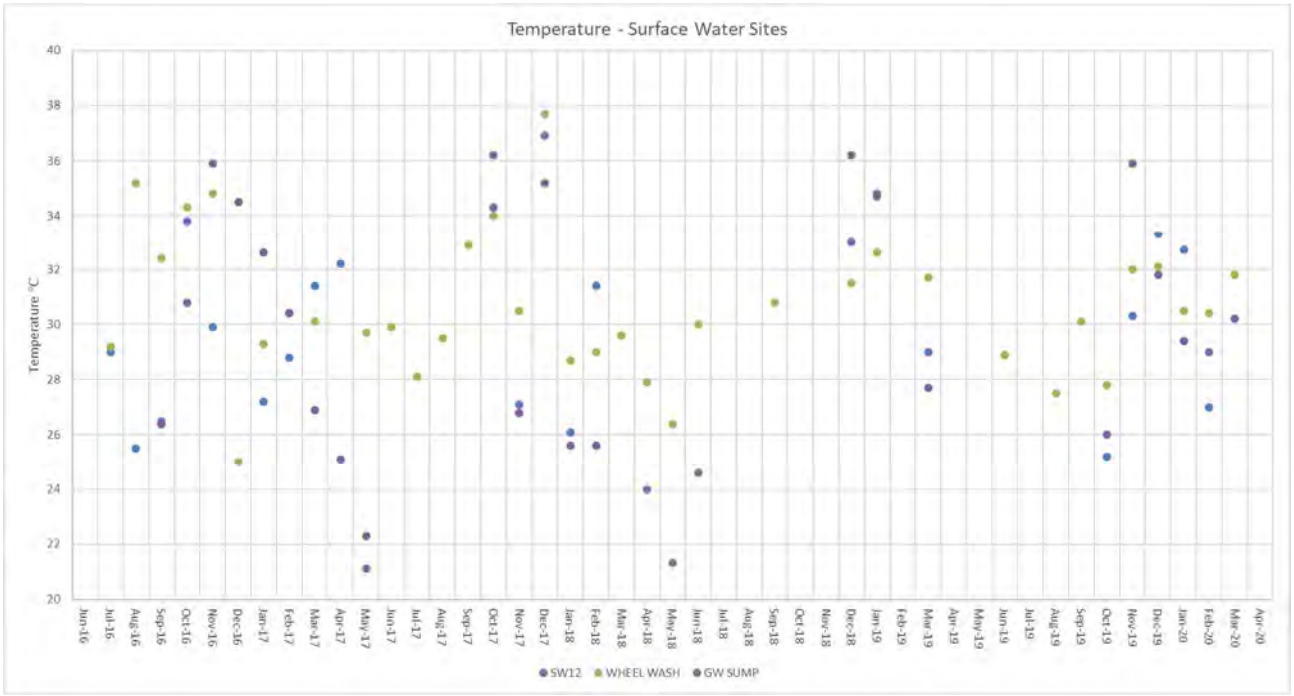
Graphs of surface water site measurements between July 2016 and March 2020.

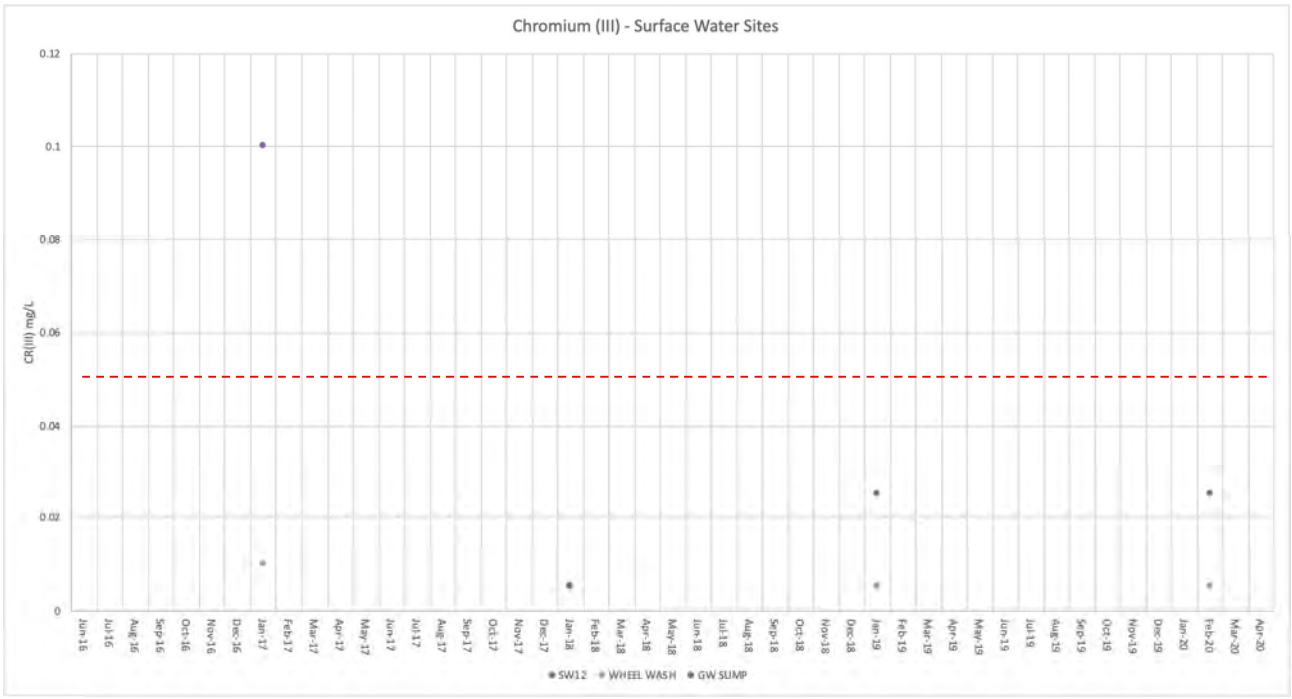


Darwin Harbour water quality objective upper and lower limits shown by red dashed lines.

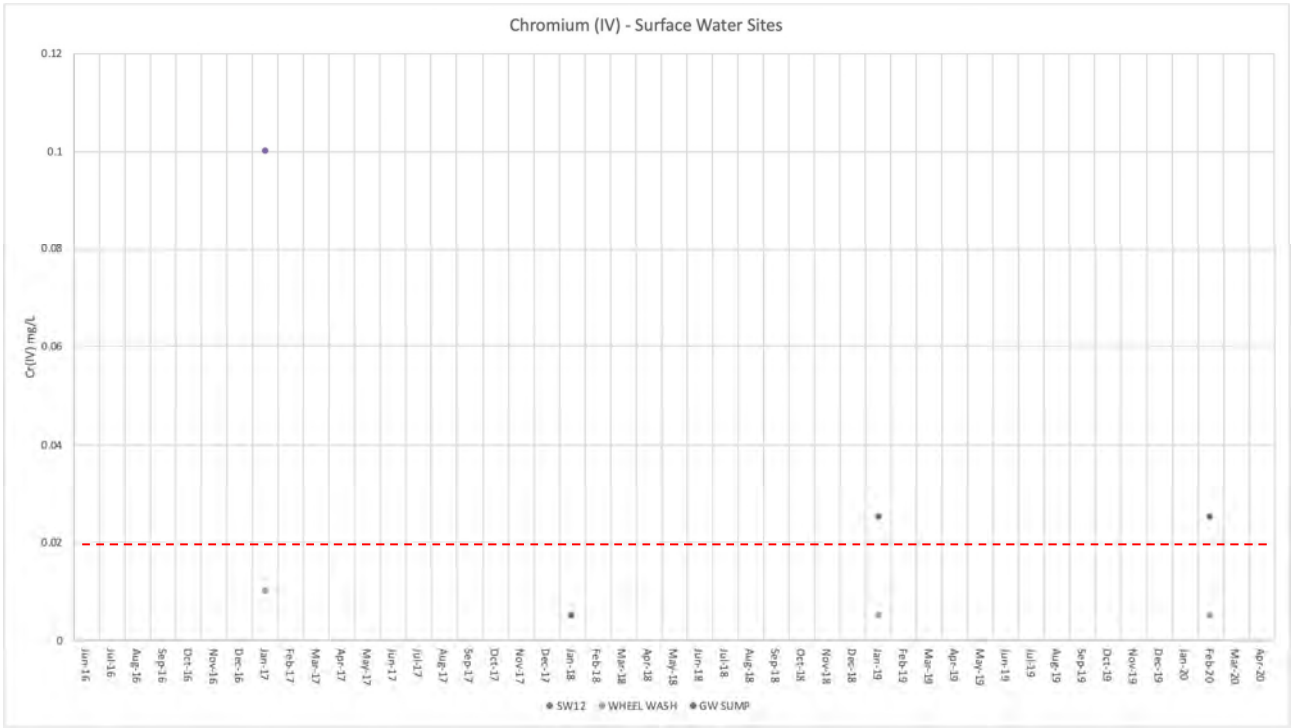



Dissolved Oxygen - Surface Water Sites
DO % Saturation
SW12
WHEEL WASH
GW SUMP

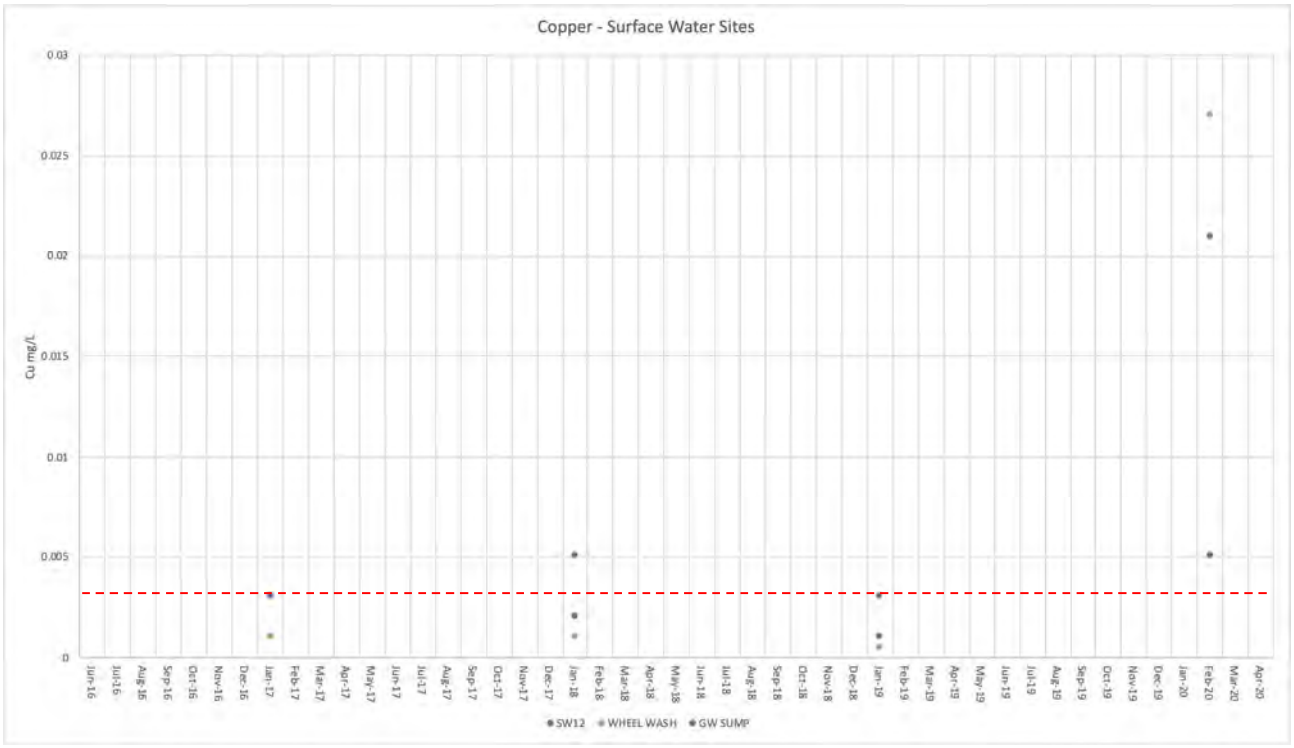

Temperature - Surface Water Sites
Temperature °C
SW12
WHEEL WASH
GW SUMP



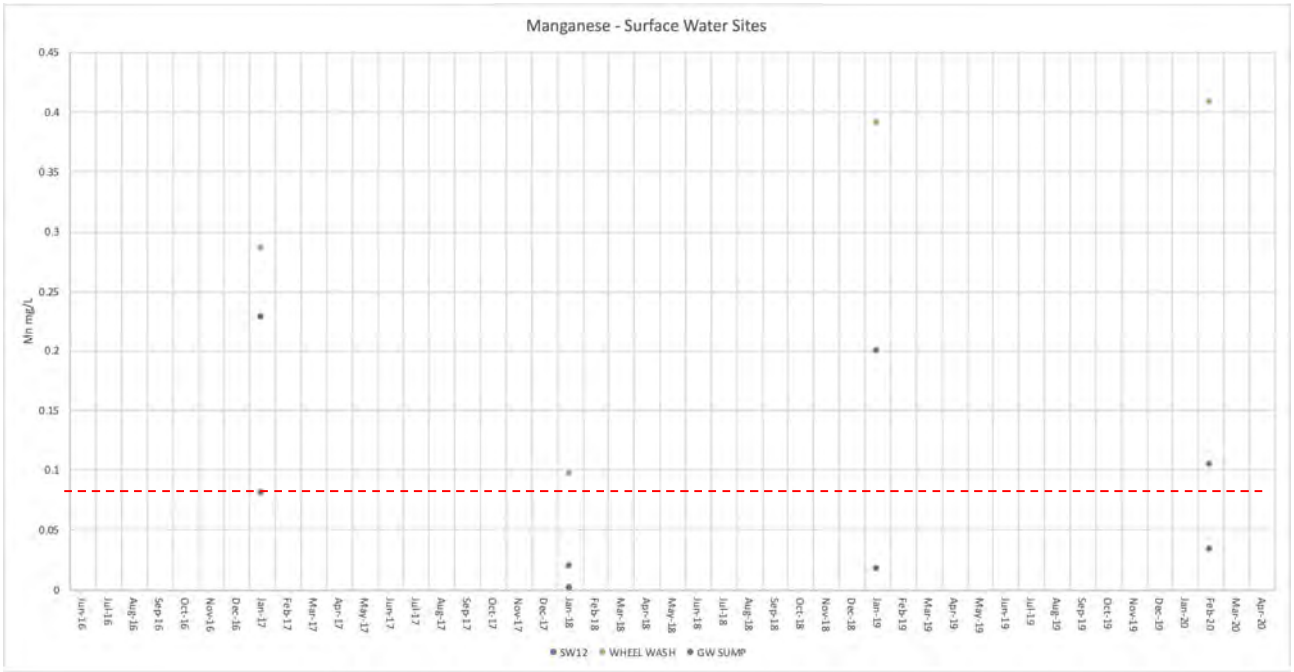
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.049 mg/L.



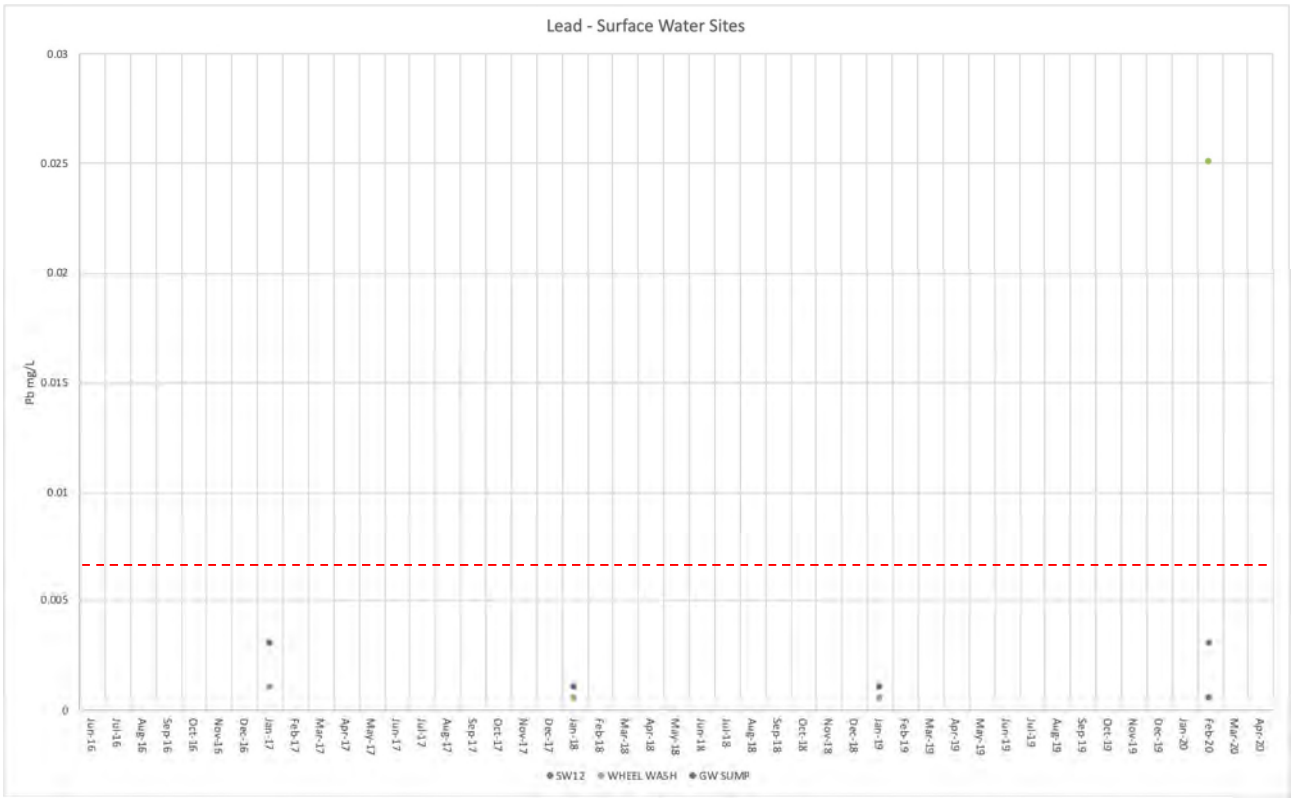
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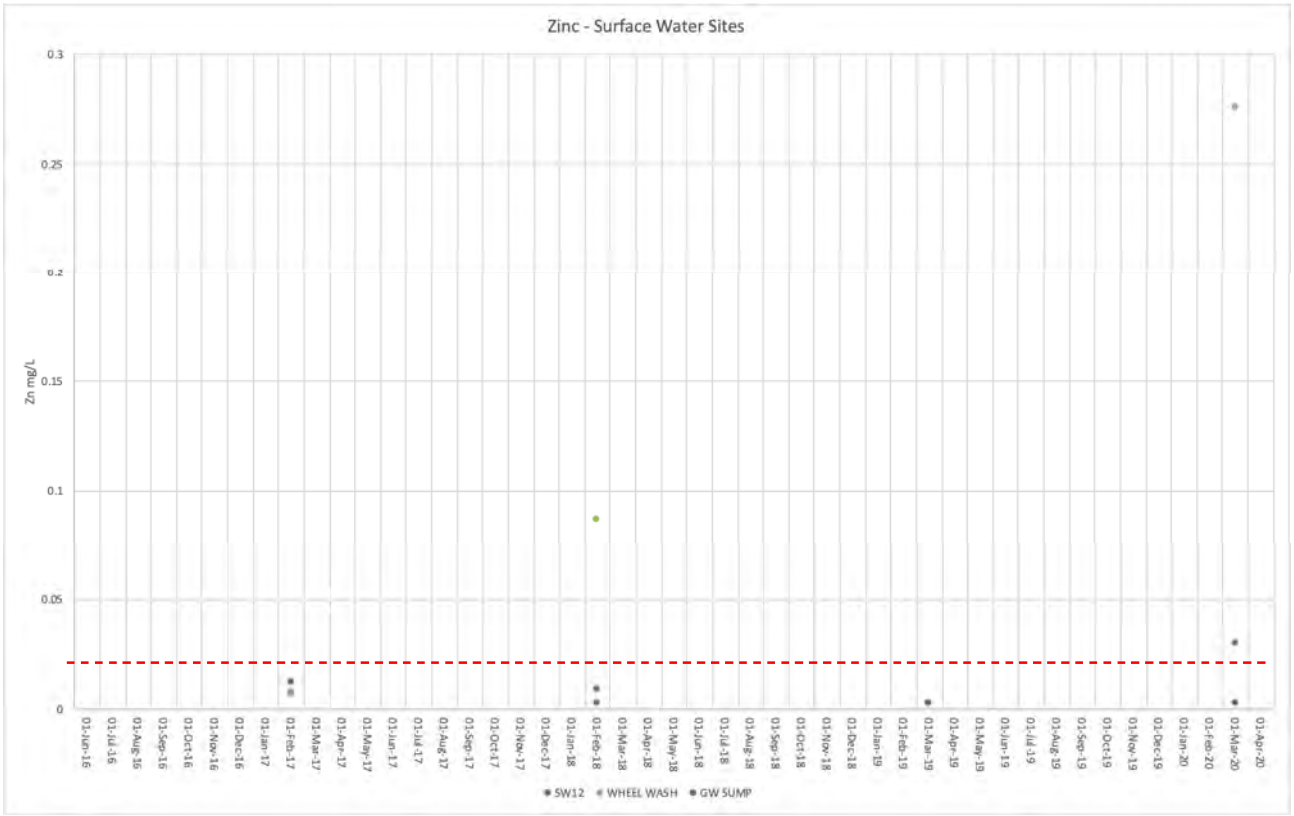
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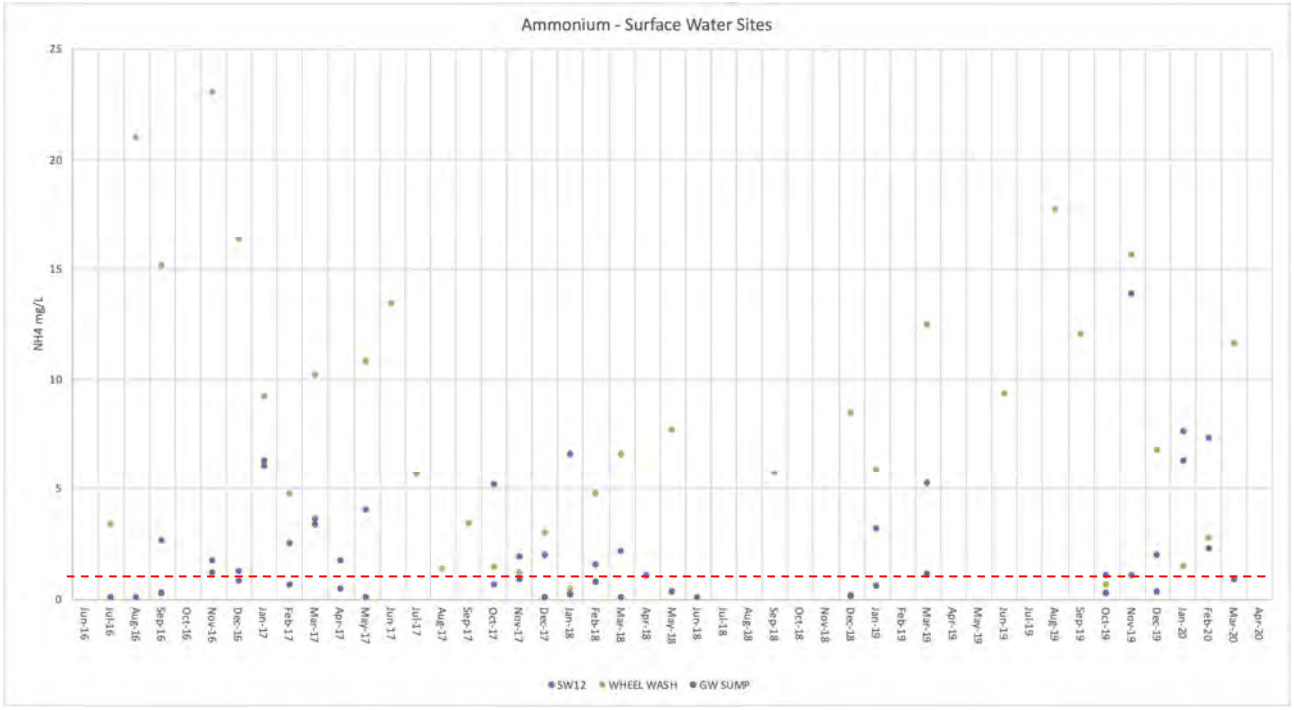
ANZECC (2000) 'low reliability' trigger value in marine water shown by red dashed line i.e. 0.08 mg/L. This value is based on limited data and should be considered as indicative only. No species protection level is indicated.



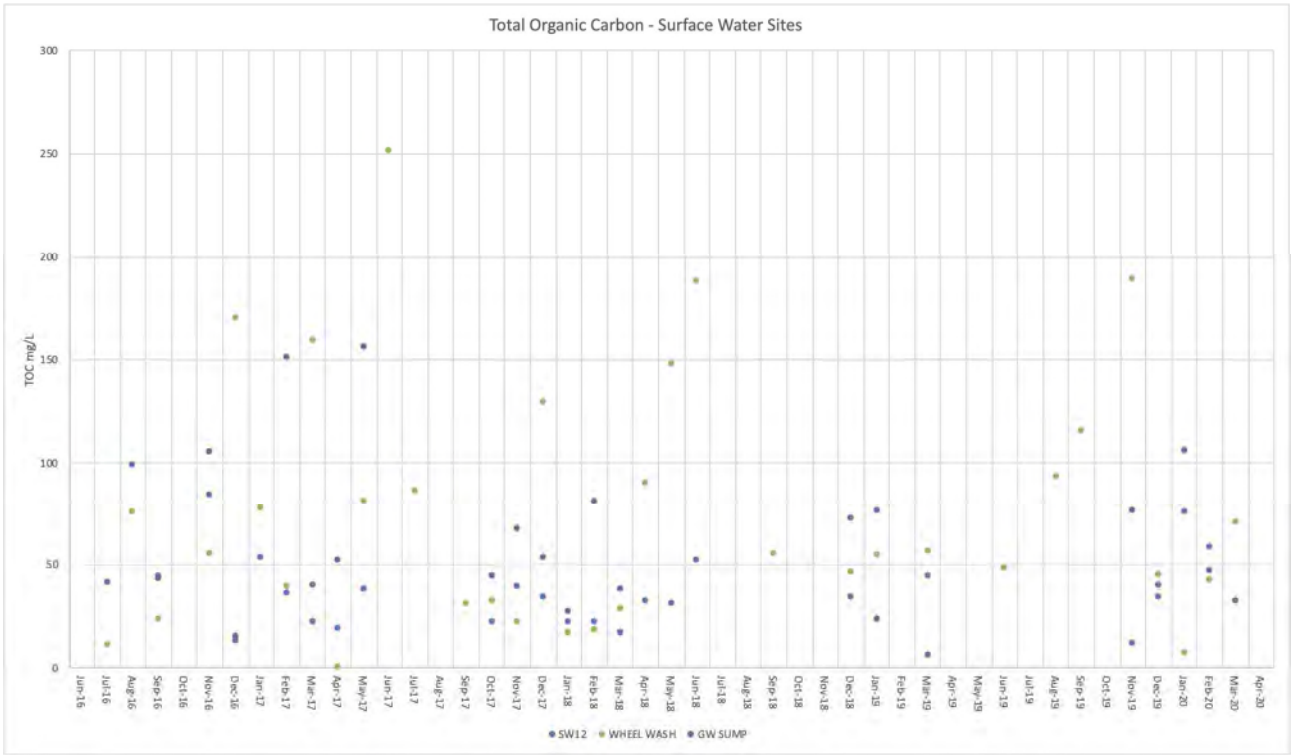
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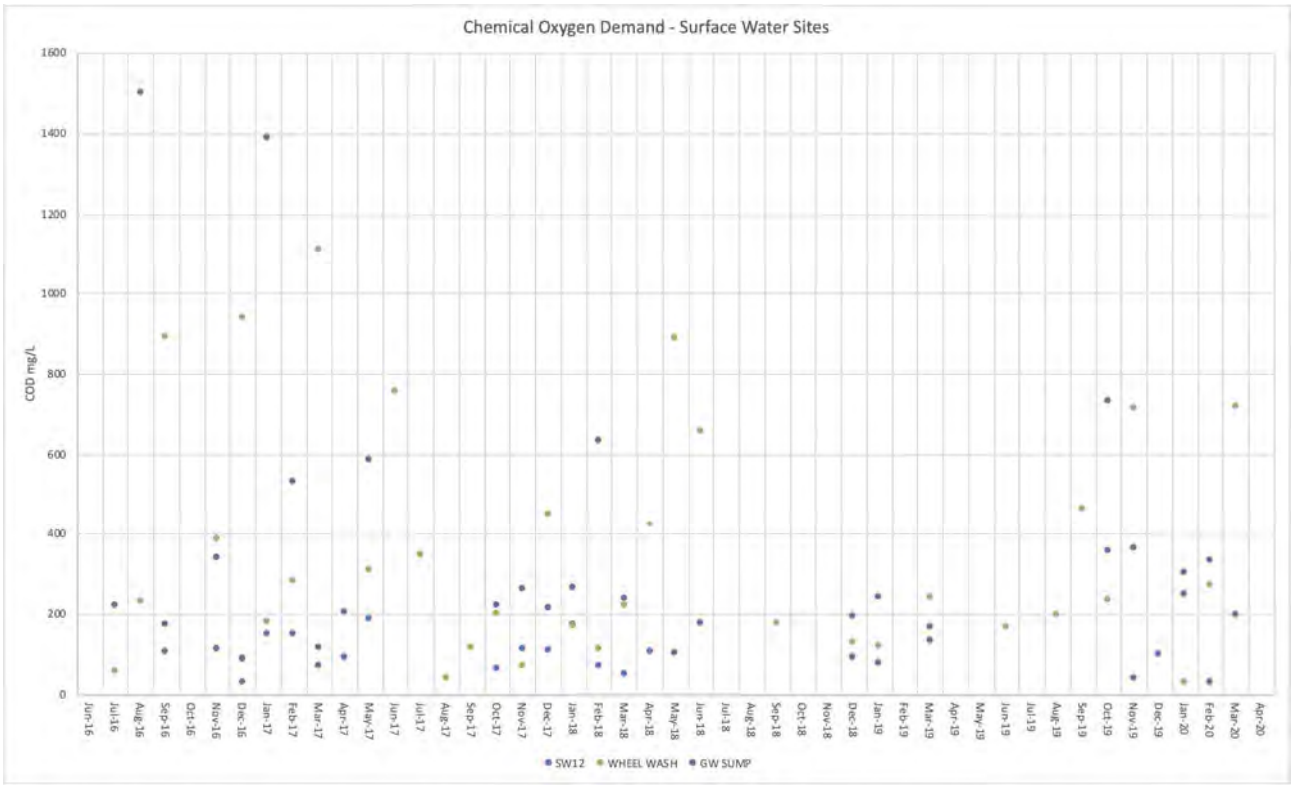
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.023 mg/L.



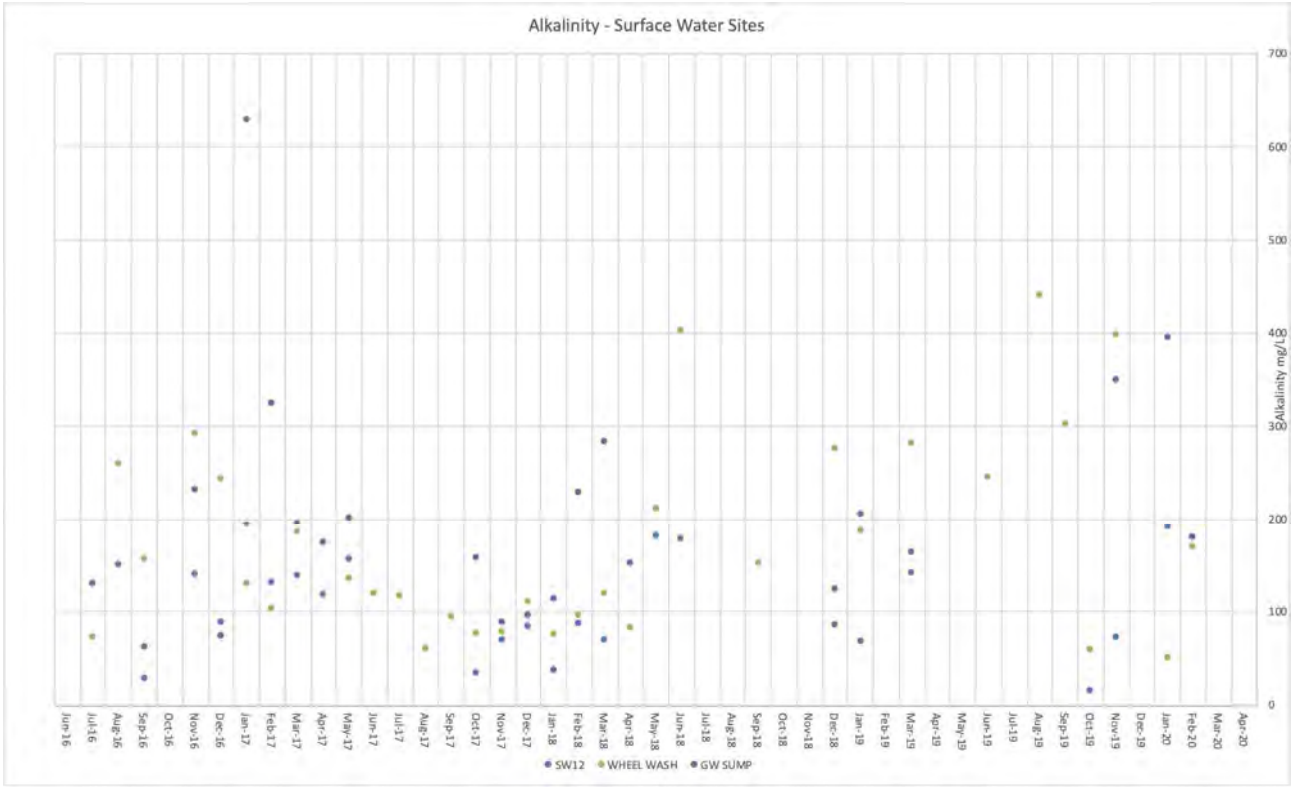
ANZECC (2000) trigger value for 90% species protection in marine water for NH_3-N is 1.2 mg/L. This is applied here (i.e. red line) as only NH_4^+ as N data is available monthly for surface water sites and comparison of NH_4^+ as N results to NH_3-N (where available) shows that NH_3-N is usually only slightly higher than NH_4^+ as N.



There is no ANZECC (2000) guideline value for TOC.

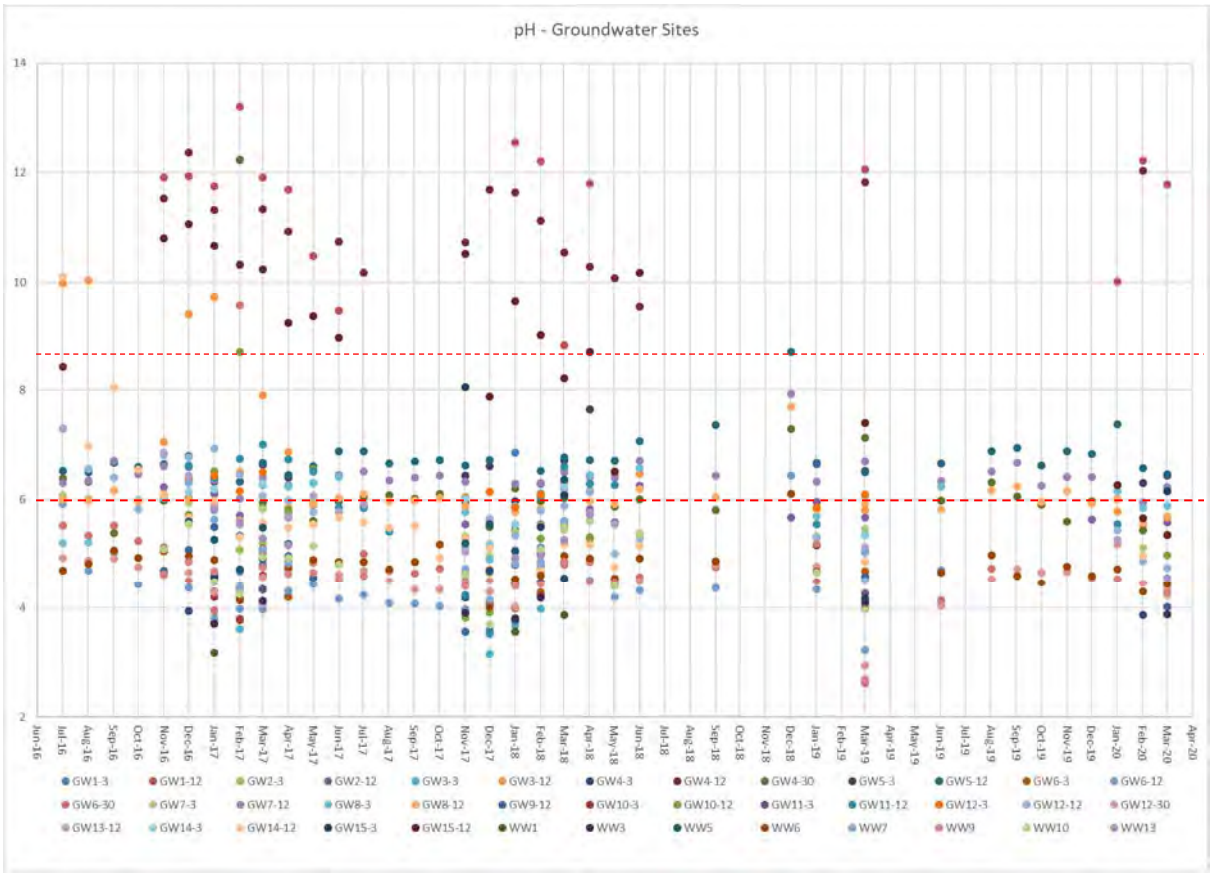


There is no ANZECC (2000) guideline value for COD.

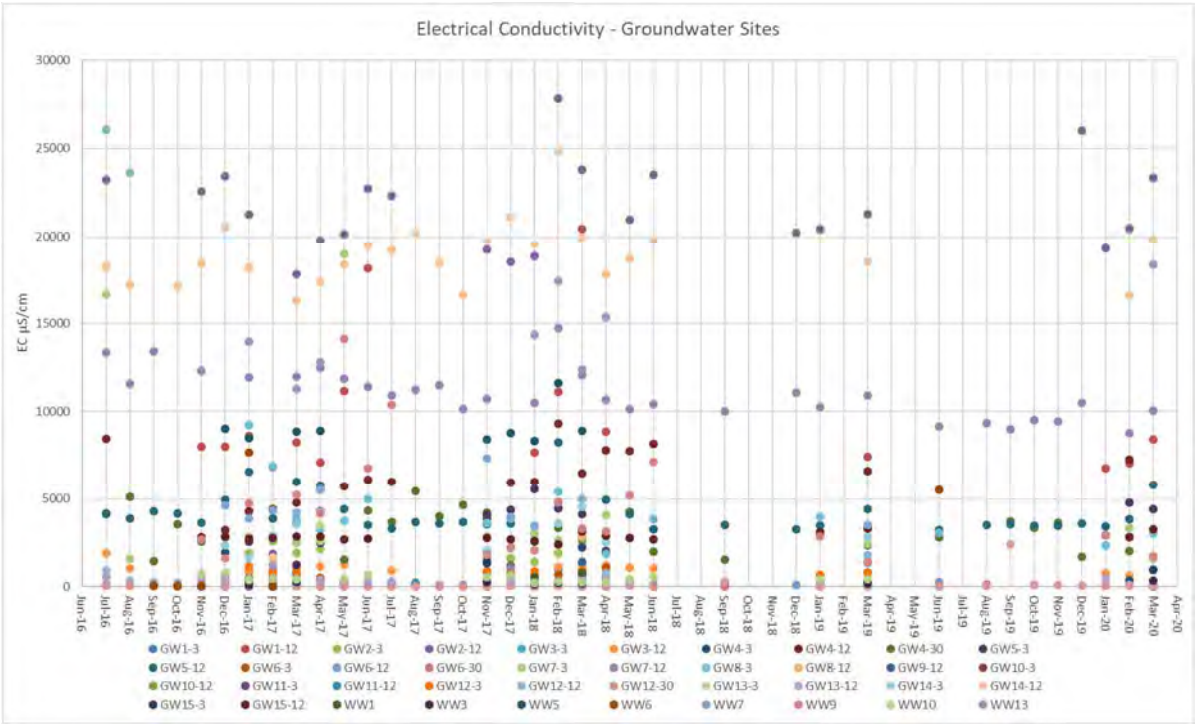


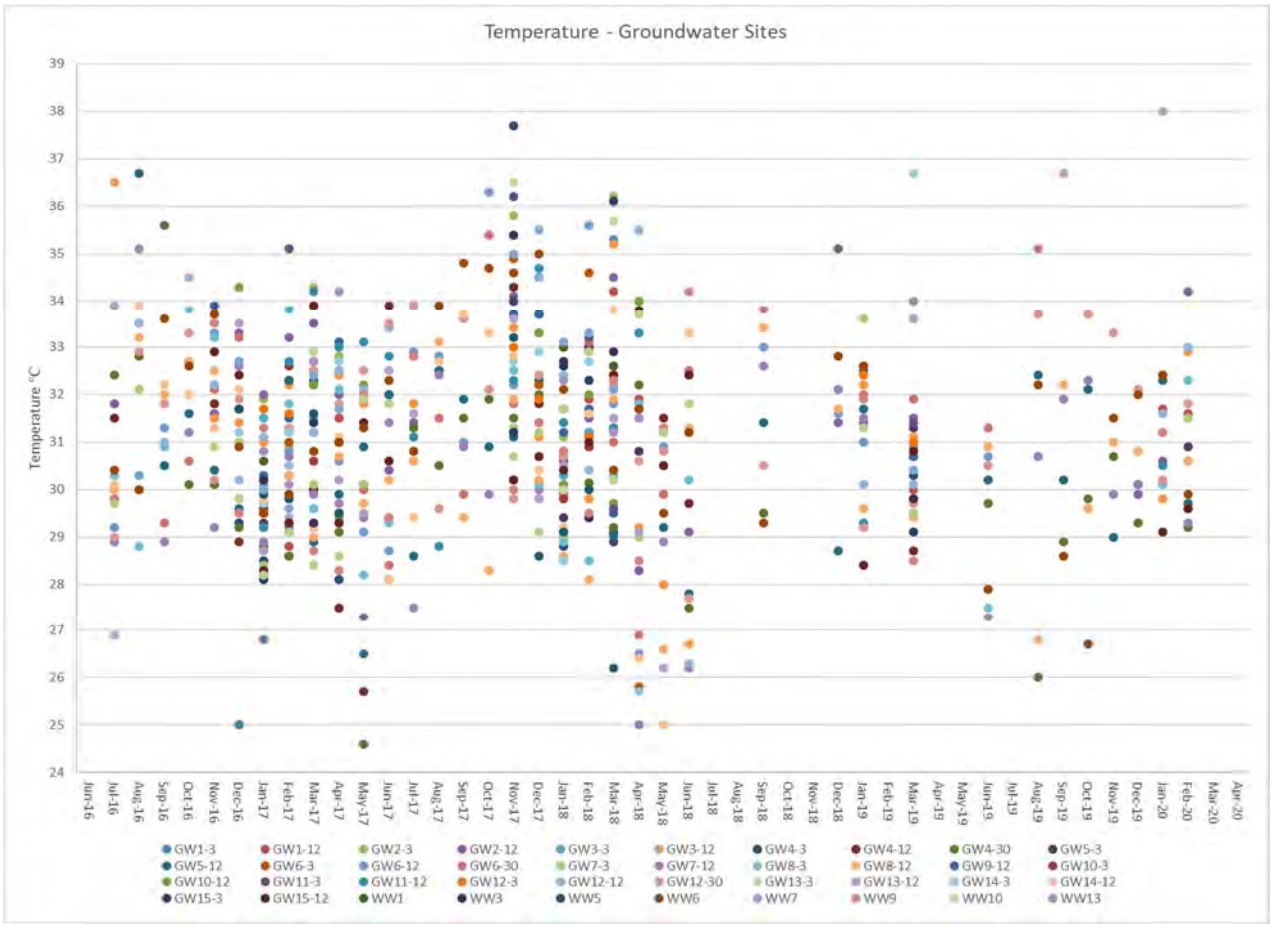
There are no ANZECC (2000) guideline values for alkalinity.

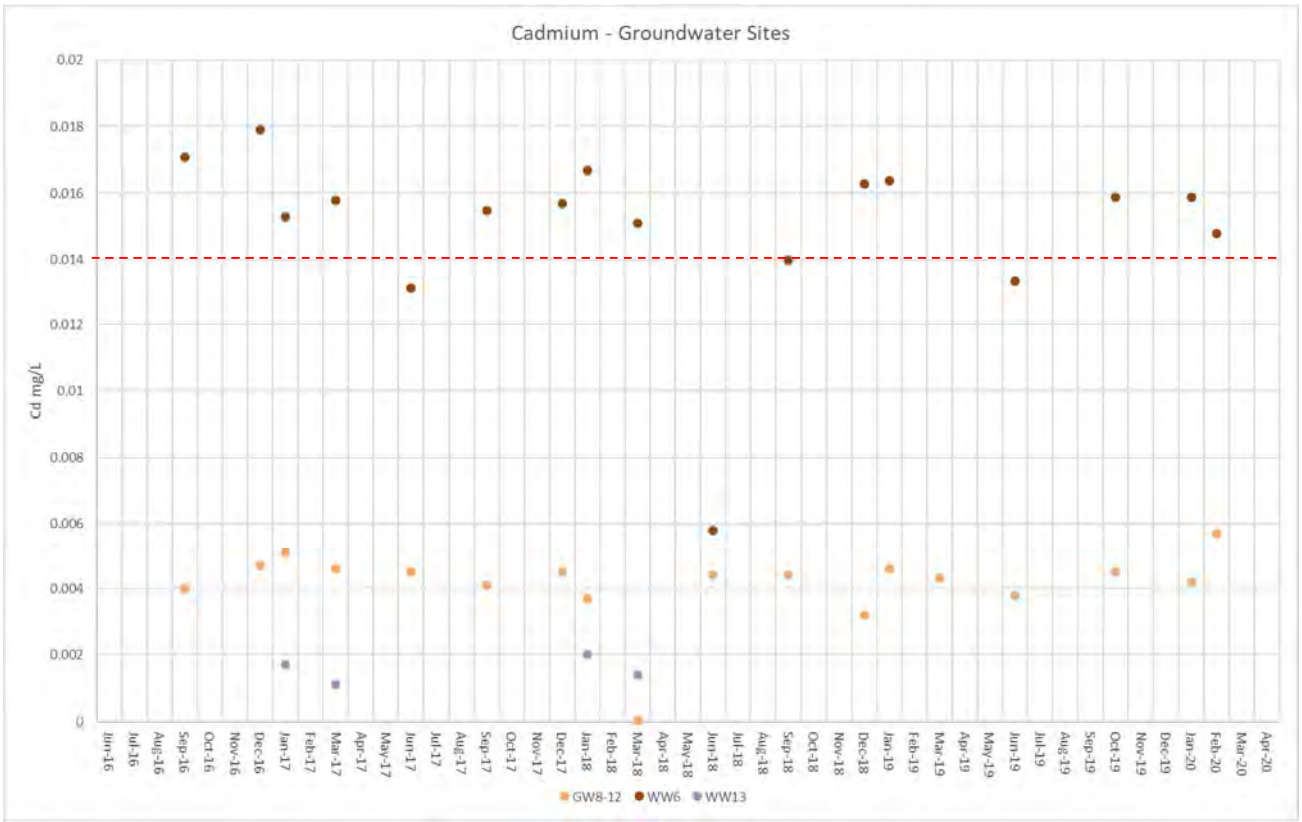
Graphs of groundwater bore measurements between July 2016 and March 2020.



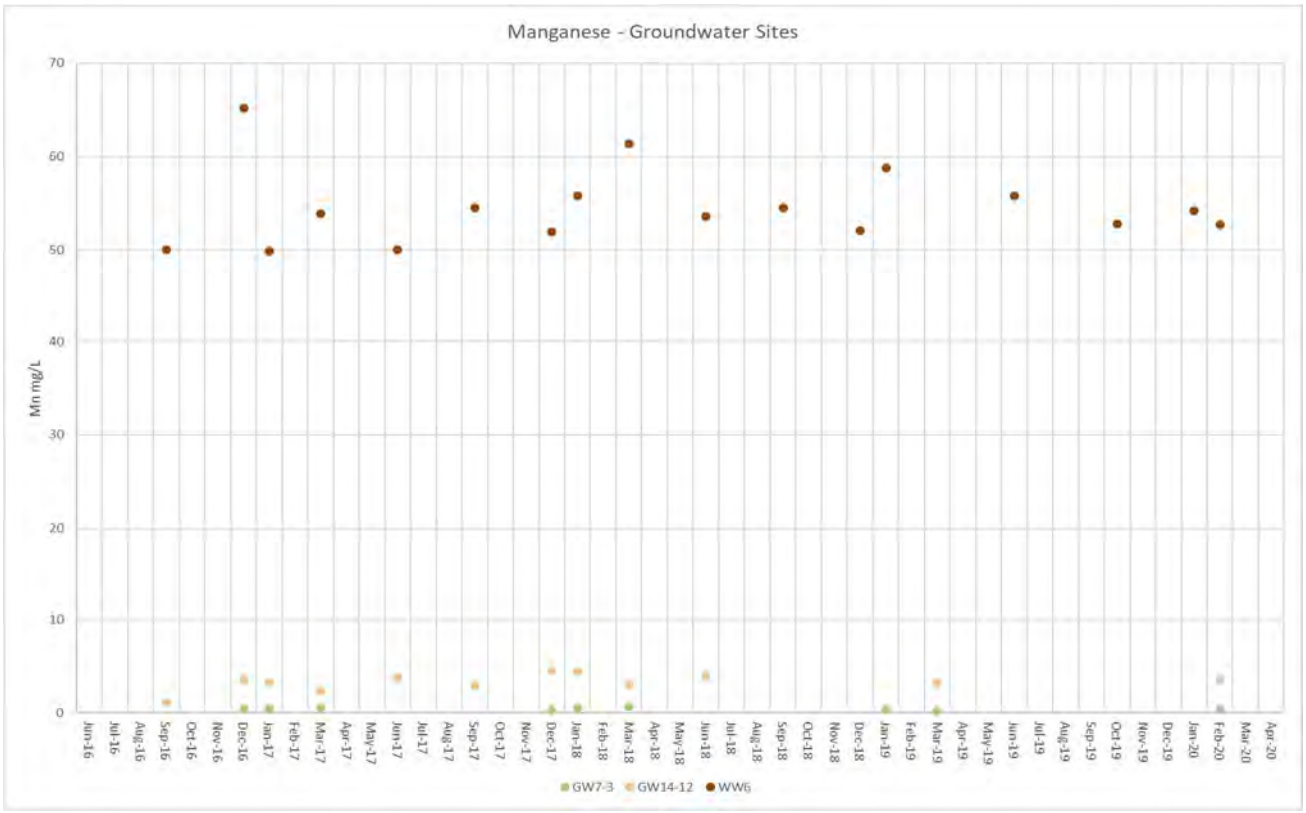
Darwin Harbour water quality objective upper and lower limits shown by red dashed lines.



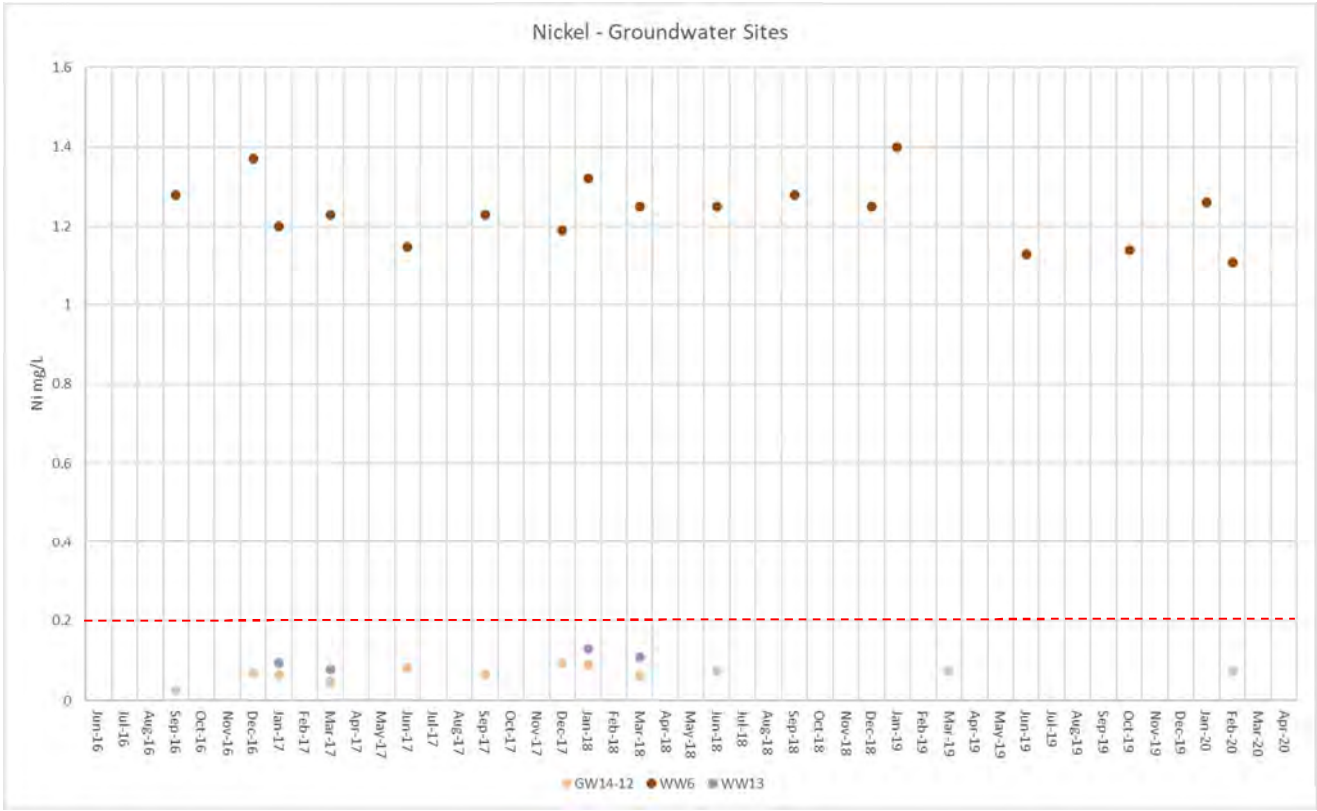




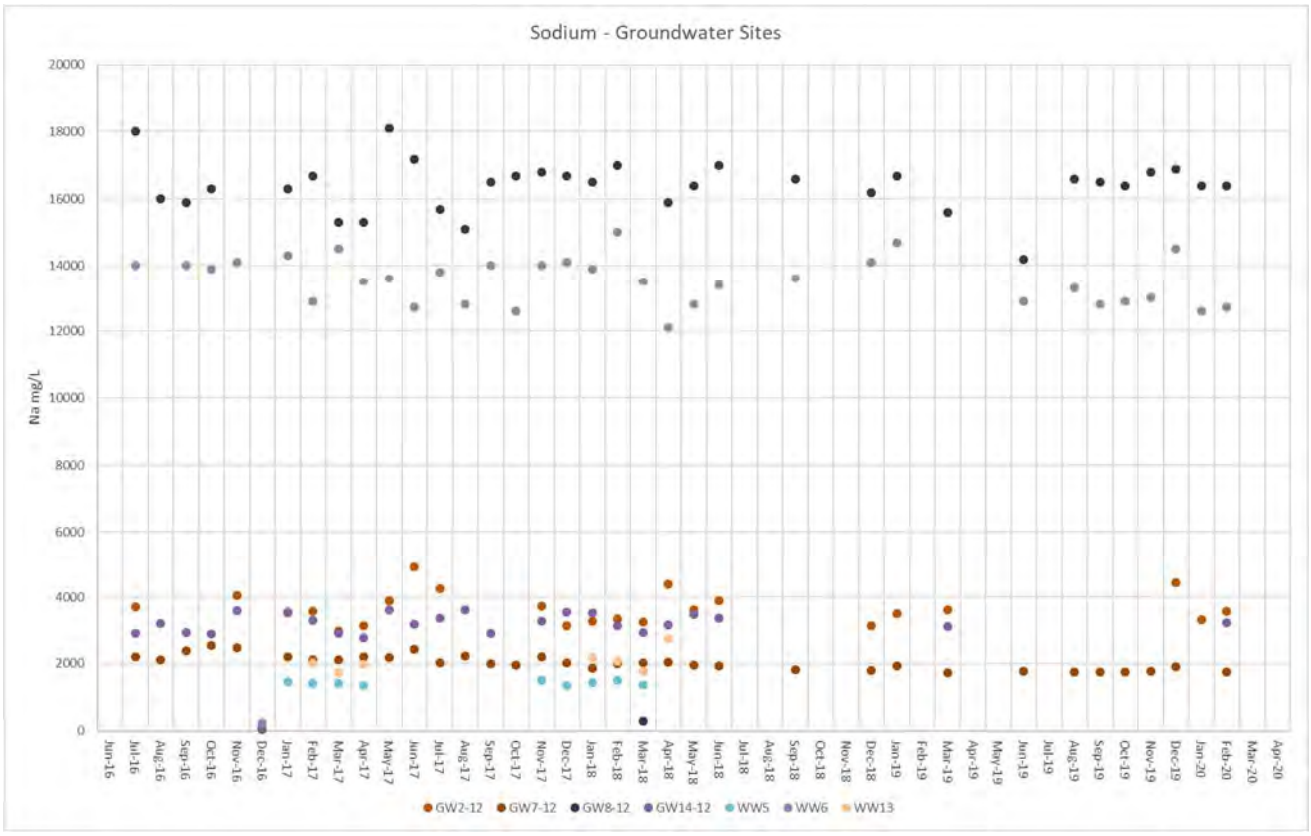
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.014 mg/L.



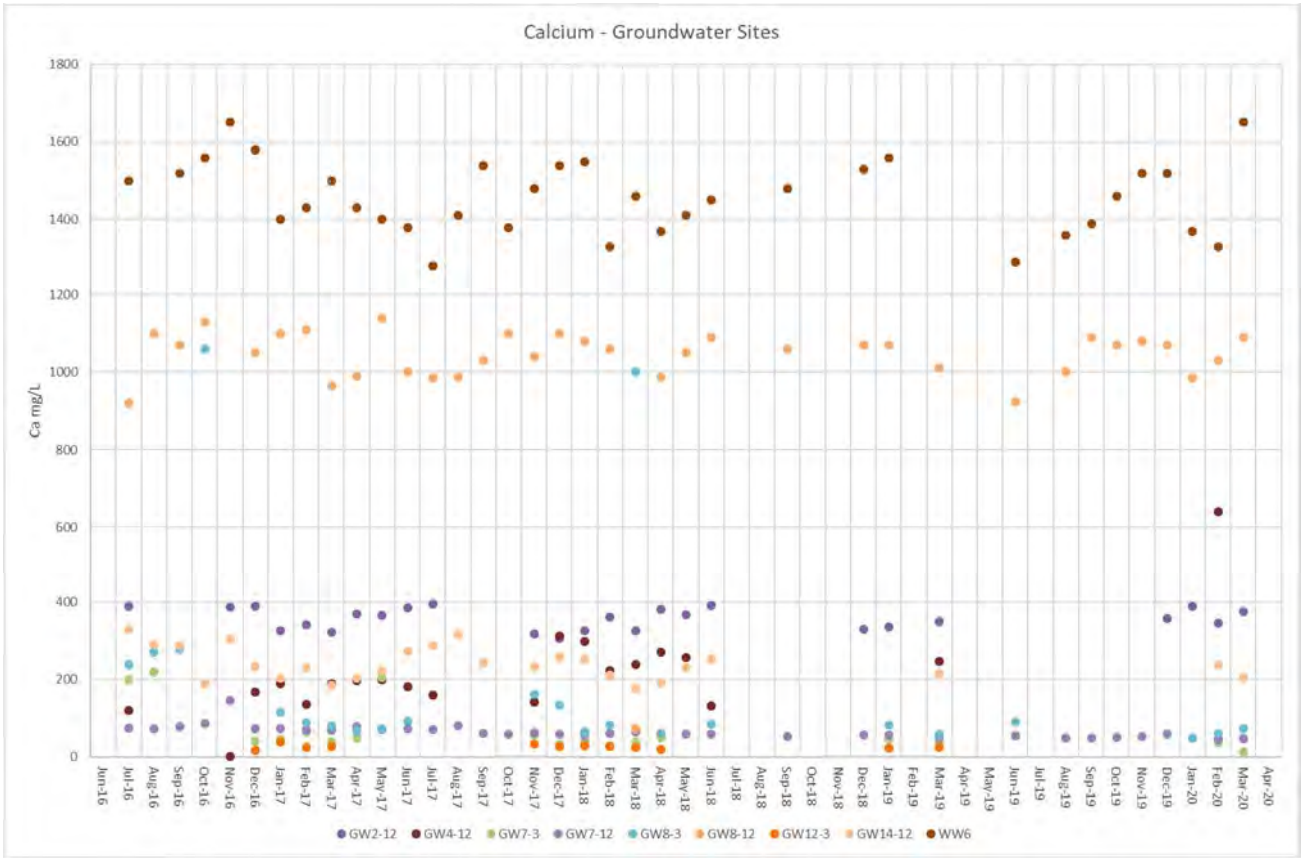
ANZECC (2000) 'low reliability' trigger value in marine water is 0.08 mg/L, which is too small to be shown on this graph. This trigger value is based on limited data and should be considered as indicative only. No species protection level is indicated.



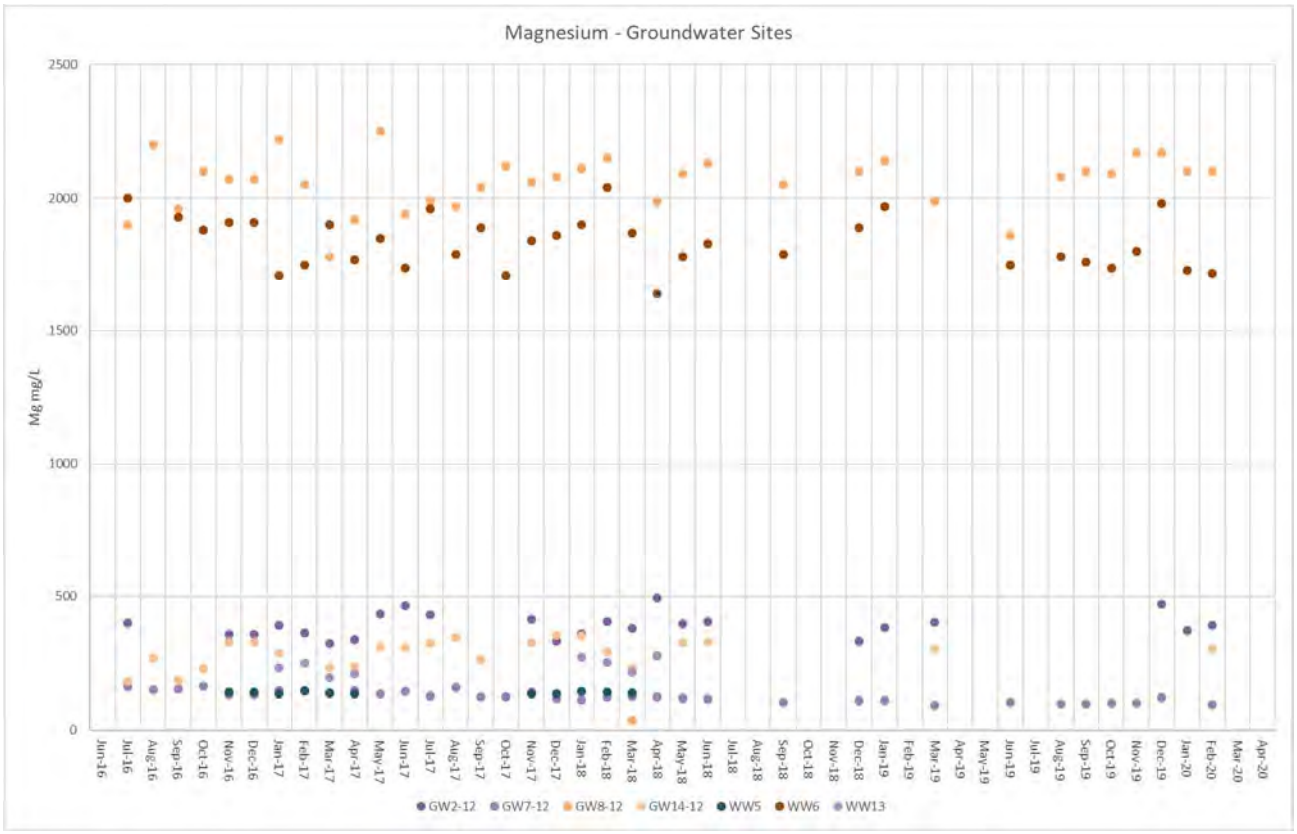
ANZECC (2000) 90% species protection in marine waters is shown by red dashed line i.e. 0.2 mg/L.



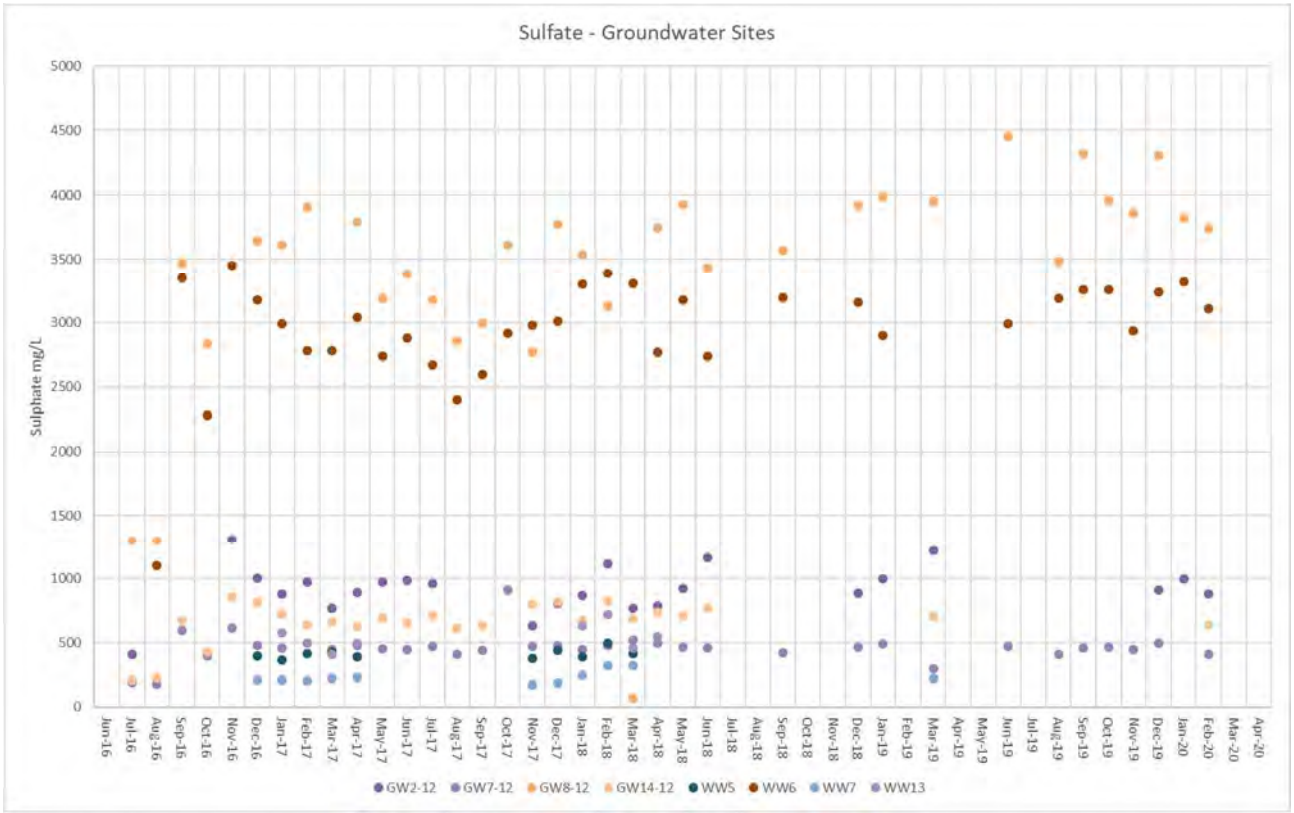
There are no ANZECC (2000) guideline values for anions and cations.



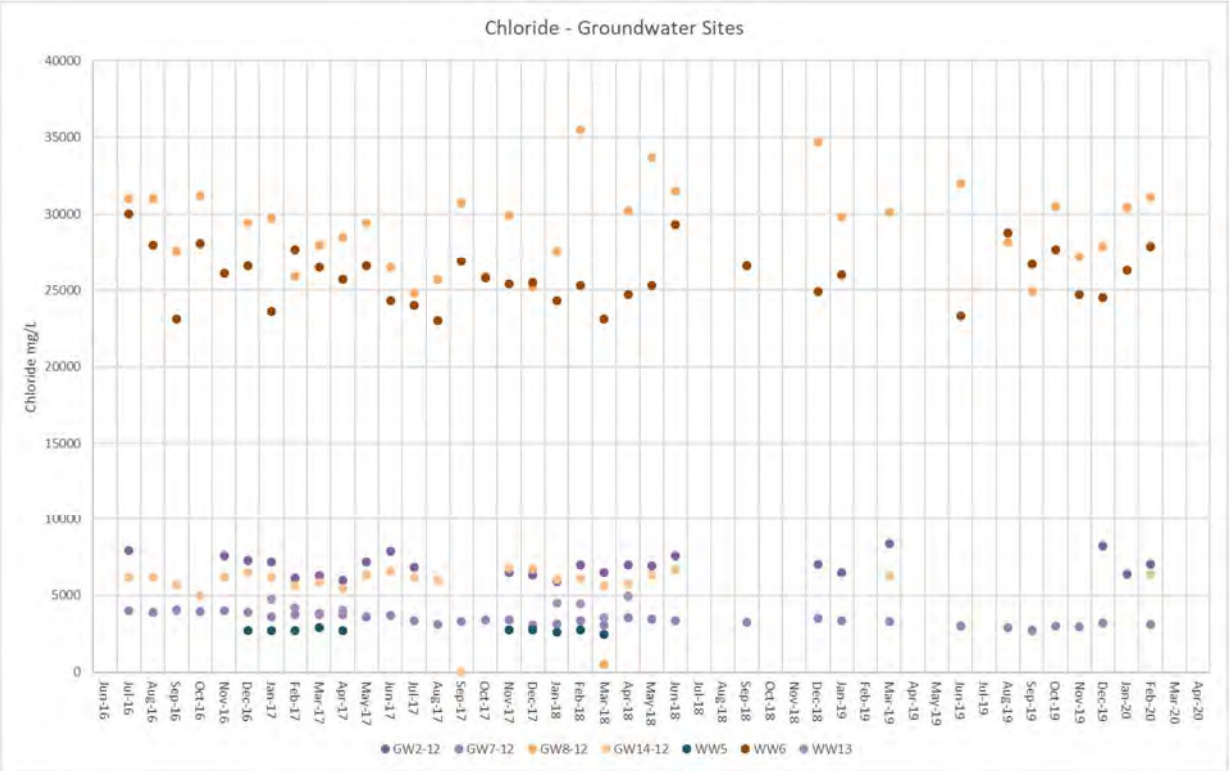
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APPROVED COMPANY ISO 14001 Environmental Management Systems QMS Certification Services

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems QMS Certification Services

APPROVED COMPANY ISO 9001 Quality Management Systems QMS Certification Services

Appendix B

Ambient air quality monitoring

REPORT

Ambient Air Quality Monitoring

Shoal Bay Waste Management Facility

Submitted to:

Shane Coleman
City of Darwin
GPO Box 84
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Submitted by:

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6 December 2022



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APPENDICES

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Important Information Relating to this Report

1.0 INTRODUCTION

WSP Golder was engaged by the City of Darwin (Council) with to provide professional services to support the management of existing subsurface waste hotspots located within the Stage 2 Inert Landfill at the Shoal Bay Waste Management Facility (SBWMF).

WSP Golder understands that subsurface hotspots conditions were identified on the eastern side of the landfill in late December 2021, with additional potential hotspots identified in January and March 2022 further northwards. The Northern Territory Environmental Protection Authority (NTEPA) issued an Authorised Officer Direction Notice on 19 May 2022 requiring Council to appoint a suitably qualified environmental consultant to confirm the extent of hot spot conditions, develop a strategy to extinguish these and to assess potential impacts to the environment and human health.

This report presents the results of Ambient Air Quality Monitoring Programme (AAQMP) undertaken by WSP Golder, to assess the for potential for environmental harm both onsite, and at the nearby sensitive receptors, as required by item 2) c) ii. of the NTEPA, Authorised Officer Direction Notice dated 19 May 2022. The AAQMP was conducted 5 September 2022 to 9 September 2022.

2.0 MONITORING PROGRAMME SCOPE

Table 1 summarises the scope of the AAQMP.

Table 1: AAQMP Scope – Remediation Stage

Monitoring parameter	Methodology	Location/s	Monitoring Frequency
Volatile organic compounds (VOCs)	Evacuated canister – USEPA T0-15	3 locations	Daily
Odour	Field odour survey	Onsite boundary perimeter in the down-wind direction	Daily
	Field odour survey	Residential area adjacent to site in downwind direction.	
Continuous monitoring - particulate matter with an equivalent aerodynamic diameter less than 2.5 microns ($PM_{2.5}$)	Light-scattering laser photometer.	Onsite	Continuous
Particulate matter with an equivalent aerodynamic diameter less than 2.5 microns ($PM_{2.5}$)	Low volume sampler – gravimetric method	Varying locations: on-site and residential receptors	Daily
Meteorology (MET)	Site specific MET data using a portable weather station.	Onsite	Continuous

3.0 LEGISLATIVE GUIDELINES

The following legislation and guidelines are applicable to the AAQMP:

- *NTEPA Guideline for Reporting on* Environmental Monitoring, 2016
- *National Environment Protection (Ambient Air Quality) Measure* [NEPM(AAQ)]
- *National Environment Protection (Air Toxics) Measure Monitoring Investigation Levels* (MILs)

The NTEPA reporting and monitoring guideline references the NEPM(AAQ) and NEPM (Air Toxic) as the documents for air quality reference criteria. In addition to these publications, the NTEPA also references the National Environment Protection (National Pollutant Inventory) Measure 2011 as a criteria document for air quality.

The NEPM does not contain 24 hour air quality criteria for benzene or ethylbenzene, therefore, WSP Golder has also incorporated the Victorian Environment Protection Authority (EPA Vic) *"Guideline for assessing and minimising air pollution in Victoria"* (the Air Pollution Guideline), Publication 1961 to incorporate 24 hour criteria for benzene and ethylbenzene.

3.1 NEPM (AAQ)

The National Environment Protection (Ambient Air Quality) Measure (Air NEPM) and its environmental quality objectives (EQOs) for particles (as PM_{10} and $PM_{2.5}$) apply to air quality within a region or sub-region considered to be representative of exposure of the general population. These objectives have been adopted for the purposes of comparison with results from $PM_{2.5}$ monitoring locations for the AAQMP.

3.2 NEPM (Air Toxics)

The aim of the Air Toxics NEPM is to gain a greater understanding of the levels of air toxics at specific locations where elevated concentrations are likely to occur and where the potential for significant human exposure exists. The Air Toxics NEPM established monitoring investigation levels (MILs) relevant for the Project for benzene, toluene and xylene isomers. The MILs are used purposes of comparison with results from the air toxics monitored at the boundary locations.

3.3 Guideline for Assessing and Minimising Air Pollution in Victoria

The Guideline replaces parts of the SEPP(AQM) in Victoria, which has been discontinued. The Guideline does not contain equivalent AQO to the SEPP(AQM) Schedule B intervention levels, which are used in the assessment of local or neighbourhood air monitoring data.

3.4 Air Quality Objectives

Table 2 summarises the air quality objectives (AQO) adopted for the AAQMP for the Project.

Table 2: Air Quality Objectives

Contaminant	Units	AQO	Averaging period	Reference
$PM_{2.5}$	$\mu g/m^3$	25	24 hour	NEMP (AAQ)
Benzene	$\mu g/m^3$	29	24 hour	Air Pollution Guideline (Vic)
Ethylbenzene	$\mu g/m^3$	21712	24 hour	Air Pollution Guideline (Vic)
Formaldehyde	ppb	40	24 hour	NEMP (Air Toxics)
Toluene	ppb	1000	24 hour	NEMP (Air Toxics)
Xylenes	ppb	250	24 hour	NEMP (Air Toxics)

4.0 METHODOLOGY

4.1 Volatile Organic Compounds by Evacuated Canister

The sampling for VOCs was in accordance with Golder Associates Test Method C9 "Canister (Evacuated) Sampling for VOC and Reduced Sulphur compounds: In Ambient Air and Source Emissions".

Sampling was undertaken by collecting whole air samples in electro-polished (SUMMA) stainless steel canisters fitted with a flow restricting device. 6L canisters were used to sample a 24-hour period. The canister

is under negative pressure and when opened, slowly draws a whole air sample into the canister. The canister is closed at the end of the monitoring period, while still under a negative pressure.

Canisters were sent to SGS (NATA Accreditation No. 2562) for analysis by Gas Chromatography / Mass Spectrometry (GC/MS) in accordance with USEPA Method TO-15.

The uncertainty varies with the level of component detected, SGS have report a range of uncertainty between 25.5% and 47.4%.

4.2 Odour

Field odour surveys were undertaken to assess the general amenity of the area. Assessments were undertaken by WSP Golder staff, who are trained and certified as odour assessors.

Odour intensity surveys are designed to qualify odour emissions from industry and quantify the odour level as a perceived strength. Odour intensity is the perceived strength of an odour above its threshold. Odour intensity has a seven-point scale ranging from zero to six and is based on German Standard VDI 3940:2010 "*Measurement of Odour Impact by Field Inspection. Determination of Odour Intensity and Hedonic Odour Tone*", as described in Table 3 below.

Table 3: Odour Intensity Scale

Intensity	Description
0	Not detectable
1	Very weak
2	Weak
3	Distinct
4	Strong
5	Very strong
6	Extremely strong

WSP Golder staff surveyed the downwind Site boundary and residential areas, and record the intensity of any odours present at the time, noting also potential sources of odour from the site and external sources (e.g., vehicles).

4.3 PM10/2.5 by Laser Light Scattering

This PM_{10} sampling methodology is based on the requirements of Australian Standard AS 3580.12.1.2015, "Methods for Sampling and Analysis of Ambient Air: Determination of Light Scattering – Integrating Nephelometer Method."

$PM_{2.5}$ particles were measured using a Thermo Scientific ADR-1500 particulate monitor. Ambient air is drawn through an omni-directional inlet at a flowrate of 1.19 litres per minute (L/min) before entering a PM_{10} sharp-cut cyclone. The flow stream enters an optical sensing stage where airborne particulate matter is measured by light scattering photometry.

The results of continuous measurement were averaged every 5-minutes and reported for 15-minute and 24-hour periods. The particulate monitor is self-contained with an in-built telemetry and data logging system. Regulated power is supplied from a solar panel connected to a 12V deep cycle battery.

The measurement uncertainty for $PM_{2.5}$ by Light Scattering is published as ±5% of reading (± precision) traceable to SAE Fine test dust, as stated in the ADR-1500 Instruction Manual.

4.4 $PM_{2.5}$ by Low Volume Sampler

Sampling and analysis were conducted in accordance with Golder Test Method L2 "*Low Volume Sampler (LVS) Operation, TSP, PM_{10}, $PM_{2.5}$ and PM_1 Determination – In Ambient Air*." and Australian Standard AS3580.9.10 *"Determination of Suspended Particulate Matter – $PM_{2.5}$ Low Volume Sampler – Gravimetric Method".* (NATA Laboratory Accreditation No. 1910).

$PM_{2.5}$ sampling was conducted over a 24-hour period using a Low Volume Sampler (LVS). Ambient air was drawn through a size selective inlet at a constant flowrate, with the sample then passing through a pre-weighed PTFE filter with a 0.2 µm pore size. The PTFE filters were allowed to equilibrate in a temperature and humidity-controlled environment for 24 hours before gravimetric analysis. The weight change of the PTFE filter was determined using a Mettler Toledo six figure balance. Control PTFE filters were used to check for changes in environmental conditions between weight determinations. The Mettler Toledo balance was calibrated to comply with NATA specifications (NATA Calibration Report No. 75026-MD-3, 04/08/2022). The particulate matter concentration was then calculated using the sample volume and the filter weight change.

The sampler was calibrated and maintained in accordance with AS/NZS 3580.9.10 and manufacturer's requirements.

One field blank filter was taken for each batch of filters that were deployed in the field. The field blank was used to assess if sample handling and transportation procedures bias the results.

Laboratory blanks were used to assess filter conditioning and weighing procedures.

The measurement uncertainty for $PM_{2.5}$ gravimetric determination by LVS is reported by AS3580.9.10 as ±5 µg/m^3, for a 95% confidence interval.

5.0 MONITORING LOCATION DETAILS

Three Ambient Air Quality Monitoring Stations (AAQMS) were established on and around the Site, each measuring VOCs and gravimetric $PM_{2.5}$. These are present in Figure 1.

Site 1 ("Upwind") was located to the north of the Site near the north most access roads. The Site 2 ("Onsite") monitoring location is situated in an open area in the southern section of the Shoal Bay Waste Facility, adjacent to the main carpark and east of the mulching facility. This monitoring location also included meteorological sensors (windspeed and direction, ambient temperature and relative humidity) and laser-light scattering $PM_{2.5}$ monitor.

Site 3 ("Downwind") was located downwind of the Site towards the residential area adjacent to Vanderlin Drive. A suitable sampling location within residential areas was not available.

The Site 2 and 3 monitoring locations were selected as the best available locations representing the AAQ conditions onsite and at the closest neighbouring residential properties, respectively. Consideration had to be given to availability of access, meteorological conditions, safety and siting requirements.

The Site 1 (Upwind) monitoring location was selected for the potential to differentiate ambient conditions upwind of the Site, compared to those measure near the residential area and at onsite.

Australian Standard 3580.1.1 "*Methods for sampling and analysis of ambient air. Part 1.1 Guide to siting air monitoring equipment*" sets out guidelines for the placement of ambient air monitoring equipment for a number of different scenarios. The monitoring locations established were assessed against the criteria set out in AS3580.1.1 for a neighbourhood monitoring station and are presented in Table 4.

Table 4: Monitoring Location Details

Siting requirements (AS 3580.1.1)	Location ID		
	Site 1 - Upwind	Site 2- On site	Site 3- Downwind
Co-ordinates (UTM)	709647, 8630935	709408, 8629756	707965, 8629453
Clear sky angle 120°	✓	✓	✓
Unrestricted air flow of 270° around sample inlet or 180° if inlet is on side of building	✓	✓	✓
Height above ground to inlet 2 m – 15 m	✗1	✗1	✗1
>10 m from road (VOCs)	✓	✓	✓
>50 m from road ($PM_{2.5}$)	✓2	✓2	✗3
10 m from any object with a height exceeding 2 m below the height of sample inlet	✗4	✓	✓
No extraneous sources nearby	✓	✗5	✓

Notes: 1- Due to ground conditions, the tripods supporting sampling equipment had to be set at heights where the sample inlets were between 1.65m and 1.88m above ground level.

2- Access tracks are with 50m, there are only available to site-based vehicles.

3- Vanderlin Drive is approximately 40m from the monitoring location.

4- Trees are located ~ 8 m from the monitoring location, these are situated on the opposite side of the monitor to the Site.

5- Onsite heavy vehicles raised dust however this was mitigated by a water tanker hourly.

The selected monitoring locations do not meet all the siting criteria contained in AS3580.10.1 for a neighbourhood station due to trees located near the site boundary. The presence of nearby trees and roads are a common non-compliance for ambient air quality monitoring sites, and the trees and road near Site 3 are situated on the far side of the Site and therefore, this location and Sites 1 and 2 are considered satisfactory for the purposes of this monitoring programme.



Figure 1: AAQMS locations

6.0 RESULTS

6.1 VOCs

Volatile organic compound results above the limit of reporting (LOR) are presented in Table 5, Table 6 and Table 7. All other compounds were less than the limit of reporting. All volatile organic compound results are presented in Appendix A.

There are currently no 24-hour ambient air quality objectives within the NEPM (Air Toxics) or Air Pollution Guideline for 2-butanone, cyclohexane or freon 12.

Table 5: Results: Site 1 - Upwind Location – VOCs by Evacuated Canister

Sample No	22-1855	22-1859	22-1862	22-1865	NEPM (Air Toxics)	Air Pollution Guideline (VIC)
Sample start	5/9/2022	6/9/2022	7/9/2022	8/9/2022		
Sample end	6/9/2022	7/9/2022	8/9/2022	9/9/2022		
VOCs	**Concentration µg/m^3**					
2-Butanone (Methyl Ethyl Ketone)	16	6.1	5.7	5.5		
Cyclohexane	2.9	<2	<2	<3		
Freon 12	2.5	2.5	2.6	2.5		

Note: shaded cells indicate no available 24-hour criteria

Table 6: Results: Site 2 - Onsite Location – VOCs by Evacuated Canister

Sample No	22-1854	22-1857	22-1861	22-1864	NEPM (Air Toxics)	Air Pollution Guideline (VIC)
Sample start	5/9/2022	6/9/2022	7/9/2022	8/9/2022		
Sample end	6/9/2022	7/9/2022	8/9/2022	9/9/2022		
VOCs	**Concentration µg/m³**					
2-Butanone (Methyl Ethyl Ketone)	15	6.5	5.0	5.7		
Cyclohexane	<2	<2	<2	<2		
Freon 12	2.6	2.6	2.5	2.7		

Note: shaded cells indicate no available 24-hour criteria

Table 7: Results: Downwind Location – VOCs by Evacuated Canister

Sample No	22-1853	22-1856	22-1860	22-1863	NEPM (Air Toxics)	Air Pollution Guideline (VIC)
Sample start	5/9/2022	6/9/2022	7/9/2022	8/9/2022		
Sample end	6/9/2022	7/9/2022	8/9/2022	9/9/2022		
VOCs	**Concentration µg/m³**					
2-Butanone (Methyl Ethyl Ketone)	17	7.7	6.1	6.0		
Cyclohexane	<2	<2	<2	<1.9		
Freon 12	2.7	2.5	2.5	2.6		

Note: shaded cells indicate no available 24-hour criteria

6.2 Odour

The results of the field odour surveys are presented in the following tables. In the event that two different levels of odour intensity were detected at a particular location, the highest odour intensity recorded at that point has been presented. Odour surveys were conducted both near the Site boundary and in the residential areas adjacent to the Site in the down wind direction.

6.2.1 Boundary odour surveys

The boundary odour results are present in Table 8 to Table 12.

Table 8: Boundary Survey Odour Results – 5 September 2022

Boundary monitored	Wind direction	Odour intensity & character						Burnt odour detected? (Y/N)
		Point 1 - West end	Point 2	Point 3	Point 4	Point 5	Point 6 - East end	
South	North	1 (fuel)	4 (decaying vegetation)	3 (decaying vegetation)	1 (decaying vegetation)	1 (decaying vegetation)	0	No

Table 9: Boundary Survey Odour Results – 6 September 2022

Boundary monitored	Wind direction	Odour intensity & character							Burnt odour detected? (Y/N)
		Point 1 - West end	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7 - East end	
South	North-West	1 (vegetative matter)	2 (vegetative matter)	3 (vegetative matter)	2 (vegetative matter)	1 (vegetative matter)	1 (non-descript)	0	No

Table 10: Boundary Survey Odour Results – 7 September 2022

Boundary monitored	Wind direction	Odour intensity & character							Burnt odour detected? (Y/N)
		Point 1 - West end	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7 - East end	
South	North	2 (oil)	2 (vegetative matter)	1 (vegetative matter)	1 (vegetative matter)	0	0	0	No

Table 11: Boundary Survey Odour Results – 8 September 2022

Boundary monitored	Wind direction	Odour intensity & character								Burnt odours detected? (Y/N)
		Point 1 - North end	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8 - South end	
East	West	3 (oil)	1 (non-descript)	1 (non-descript)	2 (non-descript)	3 (oil)	3 (oil)	1 (non-descript)	0	No

Table 12: Boundary Survey Odour Results – 9 September 2022

Boundary monitored	Wind direction	Odour intensity & character							Burnt odours detected? (Y/N)
		Point 1 - West end	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7 - East end	
South	North-East	2 (decaying vegetation)	3 (decaying vegetation)	2 (decaying vegetation)	1 (decaying vegetation)	0	0	0	No

Table 13: Boundary Survey Odour Results – 10 September 2022

Boundary monitored	Wind direction	Odour intensity & character							Burnt odours detected? (Y/N)
		Point 1 - West end	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7 - East end	
South	North-East	2 (vegetative matter)	3 (vegetative matter)	3 (vegetative matter)	2 (vegetative matter)	0	0	0	No

6.2.2 Residential odour surveys

The residential odour survey locations are shown in Figure 2 to Figure 5. Calm wind conditions from 6 September to 10 September 2022, meant odour surveys were conducted in the same 3 *residential pockets* each day. These are presented in

Figure 3, Figure 4 and Figure 5; showing the southern, western and northwest residential pockets respectively. Individual locations where odour measurements took place are shown in red with an alphabetical reference.

Table 14 summarises the highest odour intensity for each residential pocket and characterises the odour, where detected.



Figure 2: Residential odour survey locations: 5 September 2022



Figure 3: Residential odour survey locations (south): 6 - 10 September 2022



Figure 4: Residential odour survey locations (west): 6 - 10 September 2022



Figure 5: Residential odour survey locations (northwest): 6 - 10 September 2022

Table 14: Residential odour survey summary

Date	Wind Direction	Maximum odour intensity & characteristic					
		Residential pocket - south	Location	Residential pocket - west	Location	Residential pocket – northwest	Location
5/09/2022	NE - E	1 (Burnt vegetation)	H	NA	-	NA	-
6/09/2022	N / WNW	No detects	-	No detects	-	No detects	-
7/09/2022	Calm / E / NE	2 (Musty / vegetation)	B	No detects	-	No detects	-
8/09/2022	Calm / N	No detects	-	1 (Musty / vegetation)	E	1 (Slight burnt odour)	J
9/09/2022	Calm / N	4 (Smoke)	C	1 (Slight burnt odour)	H	No detects	-
10/09/2022	Calm	No detects	-	No detects	-	No detects	-

6.3 $PM_{2.5}$ by Laser Light Scattering

Onsite (Site 2) $PM_{2.5}$ concentrations by laser-light scattering are presented in

Figure 6 and Figure 7, as 5-minute averages with temperature and relative humidity, and 1-hours averages respectively.

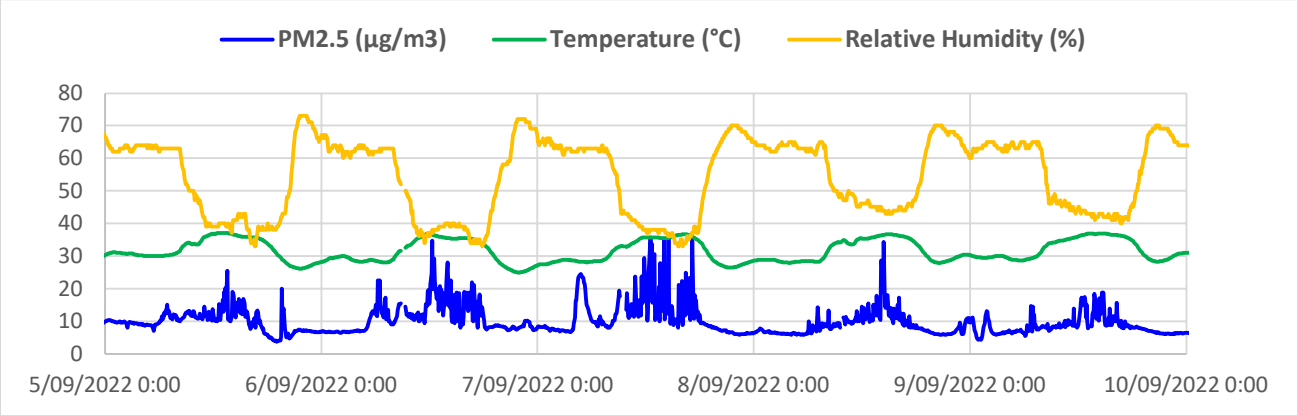


Figure 6: ADR data: 5-minute averages

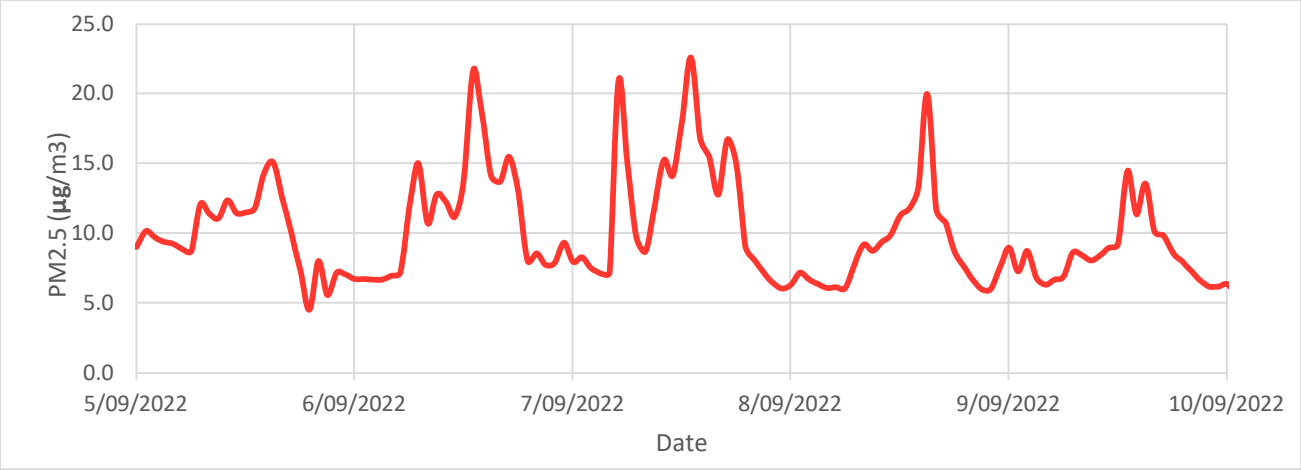


Figure 7: $PM_{2.5}$ 1-hour averages

6.4 $PM_{2.5}$ by Low Volume Sampler

The results of the $PM_{2.5}$ monitoring is presented in Table 15.

Table 15: $PM_{2.5}$ Results

Sampling Date	Site 1 – Upwind		Site 2 – Onsite		Site 3 – Downwind	
	Sample No.	$PM_{2.5}$ Concentration (µg/Nm^3)#	Sample No.	$PM_{2.5}$ Concentration (µg/Nm^3)#	Sample No.	$PM_{2.5}$ Concentration (µg/Nm^3)#
5 – 6/09/2022	22-1876	26	22-1871	33	22-1866	16
6 – 7/09/2022	22-1877	35	22-1872	65	22-1867	24
7 – 8/09/2022	22-1878	26	22-1873	86	22-1868	12
8 – 9/09/2022	22-1879	28	22-1874	110	22-1869	21
NEPM (AAQ)	25 µg/m^3					

Notes: # – Concentrations are expressed as micrograms per cubic metre at 0°C and 101.3kPa

6.5 Meteorology

Meteorological data had been measured and reported for the sampling period; 00:00, 5 September 2022 to 23:59, 9 September 2022. Ambient temperature, relative humidity, wind speed and wind direction are shown in the following figures.

Figure 10 and Figure 11 presents the wind direction and speed and frequency distribution measured by the Davis instrument installed Onsite (Site 2). For the duration of the AAQM period, the wind speed was very low, with winds registered as either Calm or below 2.1 m/s for over 60% monitoring period as seen in the frequency distribution figure. Typically, the winds were recorded blowing from the northwest, or northeast.

Winds speeds recorded above 2.1 m/s, were measured blowing from the north and followed a diurnal pattern with peaks during the afternoon, and little to no wind overnight.

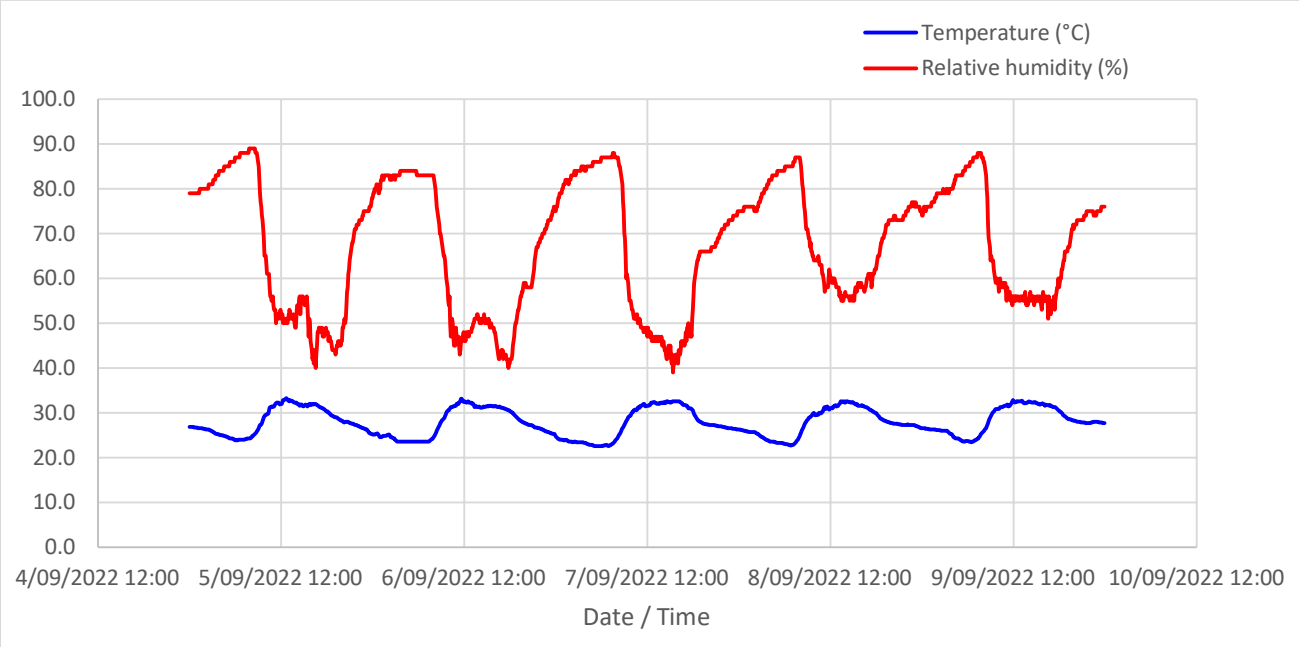


Figure 8: Temperature and relative humidity

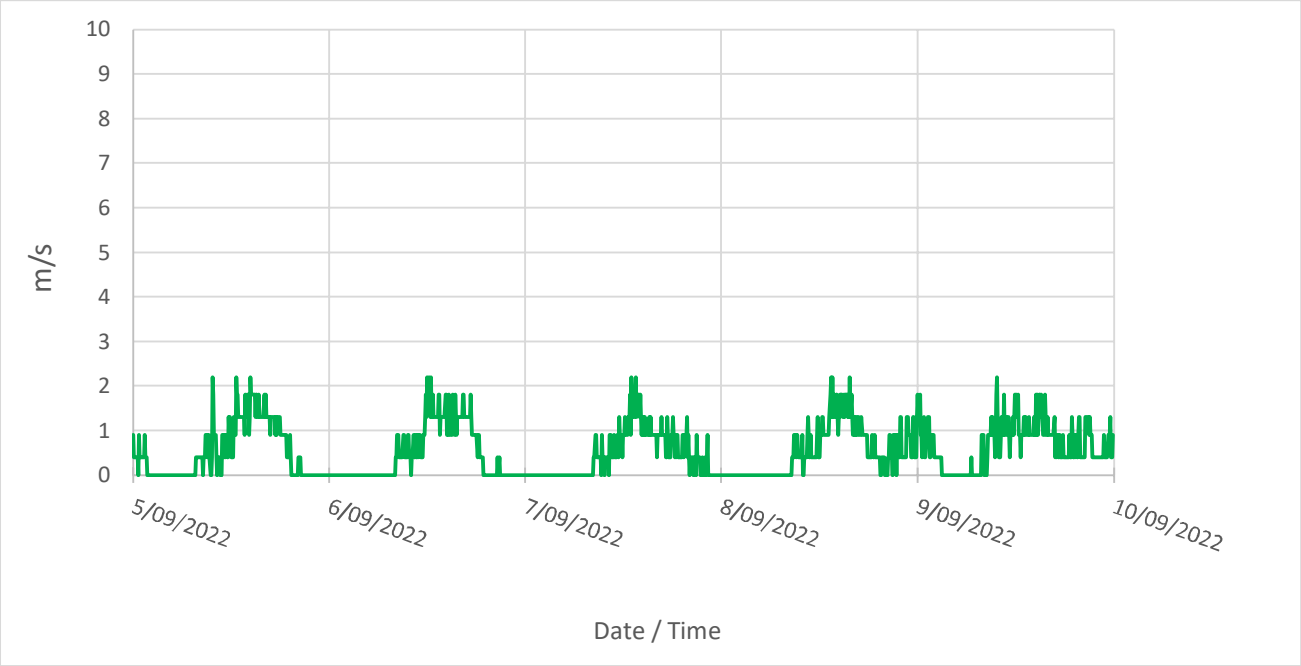


Figure 9: Wind speed (m/s)

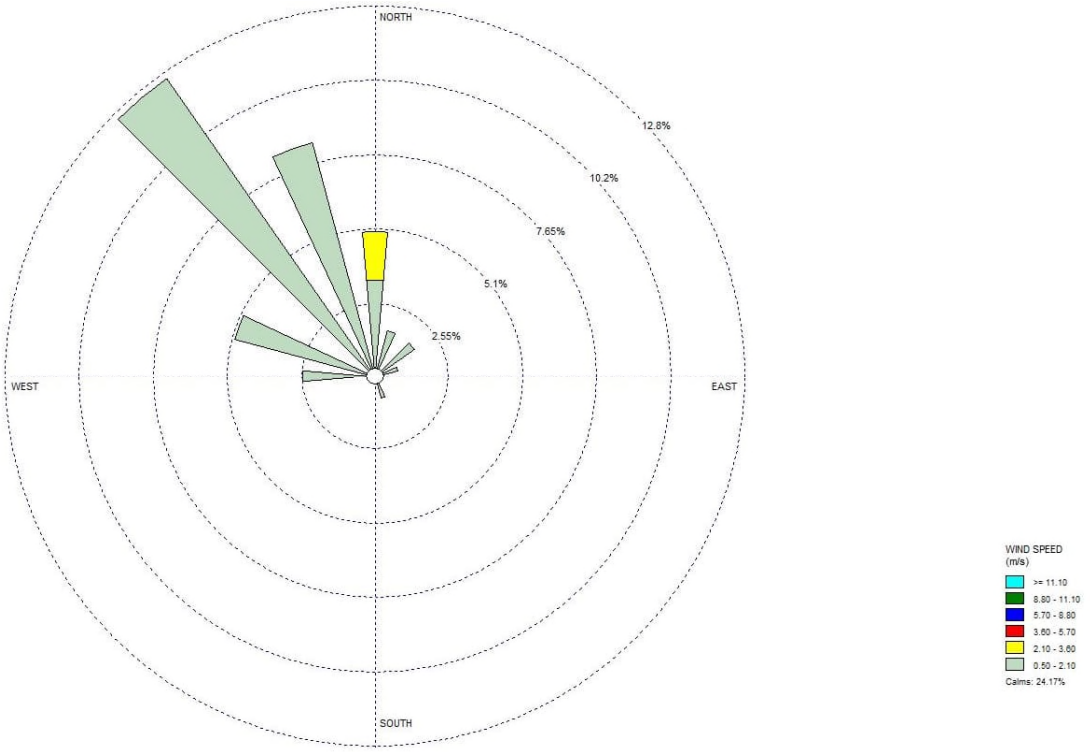


Figure 10: Wind rose plot: wind direction (5 – 9 September 2022)

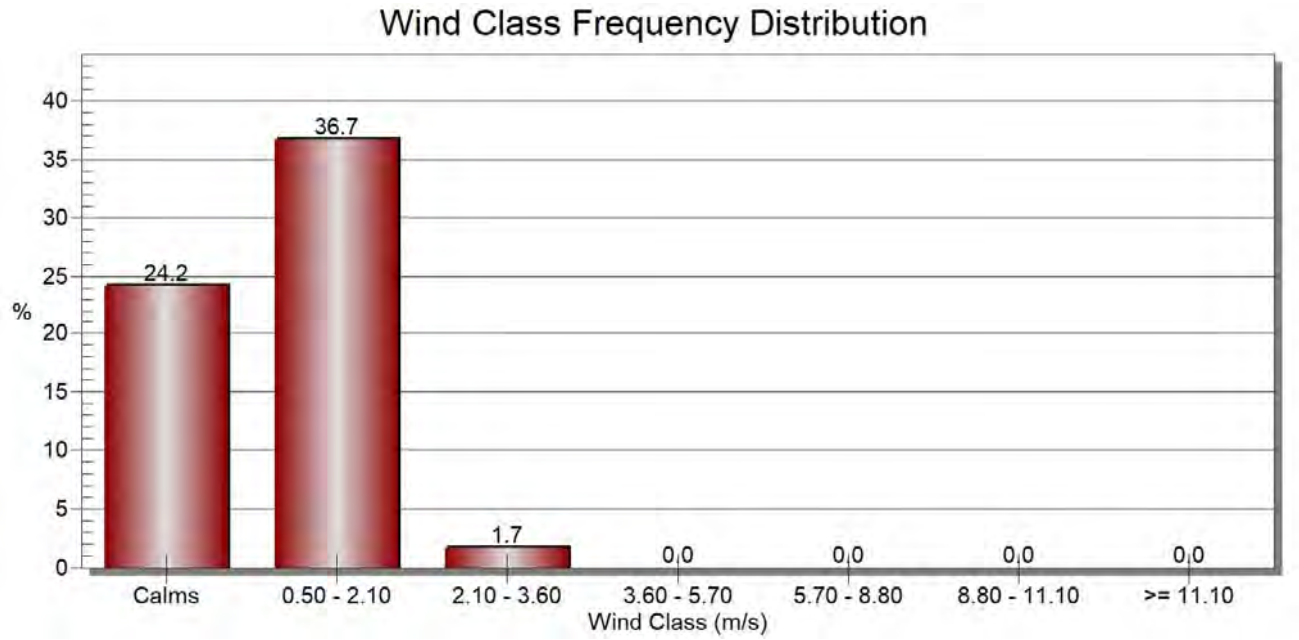


Figure 11: Wind frequency distribution (5 - 9 September 2022)

7.0 QUALITY ASSURANCE / QUALITY CONTROL

The Quality Assurance / Quality Control (QA/QC) measures undertaken during the monitoring programme are described below.

7.1 VOCs

Details of the QA/QC measures taken, together with the data quality objectives are listed below.

Table 16: QA/QC - Volatile organic compounds

Measure	Frequency	Data Quality Objective (DQO)	DQO compliance
Leak check	Each canister	No leaks	✓
Laboratory control spikes	Once per batch.	60% - 140%	✓
Laboratory duplicate analysis	Once per batch.	< 30% RPD*	✓

*RPD – Relative percentage difference

7.2 Odour

WSP Golder staff undertaking field odour surveys participate in annual screening sessions that assess their responsiveness to a reference odour (n-butanol). All staff have been screened within the past 12 months and their Individual Threshold Estimates (ITEs) were within the acceptable range.

7.3 $PM_{2.5}$

Details of the QA/QC measures taken, together with the data quality objectives are listed below.

Table 17: QA/QC – $PM_{2.5}$

Measure	Frequency	Data Quality Objective (DQO)	DQO compliance
Field blank	1 per batch deployed in the field (1 per 10 samples).	30 µg	✓
Laboratory Control	1 per 10 samples.	15 µg	✓
Sample flow calibration of sampling unit	Initial deployment	Within manufacturers specifications	✓
LVS flow check	Upon completion of deployment	Within manufacturers specifications	✓

8.0 DISCUSSION

The AAQMP conducted by WSP Golder from 5 September 2022 to 9 September 2022, was undertaken to assess the for potential for environmental harm both onsite, and at the nearby sensitive receptors, as required by item 2) c) ii. of the NTEPA, Authorised Officer Direction Notice dated 19 May 2022. The AAQ parameters assessed were VOCs and reduced sulphur compounds by Summa canister, $PM_{2.5}$ (by light-scattering nepholometer and low-volume sampler), and odour.

Summa canisters samples were collected at 3 locations; Upwind, Onsite and Downwind, and were analysed for a suite of 87 VOC and sulphur compounds. Three compounds were detected above the limit of reporting, these are 2-butanone, cyclohexane and freon 12. All other compounds were below the limit of reporting. There are currently no 24-hour ambient air quality objectives within the NEPM (Air Toxics) or Air Pollution Guideline for the detected compounds.

The results for $PM_{2.5}$ by laser light-scattering, measured Onsite, and presented in 6.3, show the elevated concentrations occur during site operational hours. The $PM_{2.5}$ concentration is significantly reduced out of the site operational hours, suggesting localised $PM_{2.5}$ concentration is strongly influenced by site-based operational activities.

The low-volume sampler $PM_{2.5}$ results varying between locations. The results at the Downwind location, representing residential receptors, were all below the air quality objective of 25 µg/m^3. Upwind of the Site follows the same concentration pattern as the Downwind location. The highest $PM_{2.5}$ results at both locations occurred 6th to 7th September, the second highest result was recorded 8th to 9th September. All results at the Upwind locations were above the air quality objective of 25 µg/m^3.

The Onsite $PM_{2.5}$ results did not follow the concentration pattern of the Upwind and Downwind locations. The higher of the results measured Onsite, was notably larger than either of the other locations. Day to day, the Onsite results were also more varied than either the Upwind or Downwind locations, suggesting operational activity at the Site is likely to be a considerable contributing factor to the $PM_{2.5}$ concentration.

The results of the field and residential odour surveys, presented 6.2, were conducted each day near the Site boundary and residential areas adjacent to the Site in a down wind direction (wind permitting). No burning odour was detected during any of the boundary odour surveys, the odour assessor undertaking the work noted other odours associated with the Site at varying intensities.

The residential odour surveys resulted in no detections of odour for 90% of the surveys. In four instances over three days, 5th, 8th and 9th September, an odour described as ‘burnt’ or ‘smoke’ was detected. In three of the four instances, the odour intensity was ‘*1 – very weak*’, the other detect had an odour intensity of ‘*4 – strong*’

and was recorded 9th September. The wind direction during the residential odour survey on 9th September was recorded as 'calm' or blowing from the north and the *strong* odour detection, was recorded to the south of the Site, along Vanderlin Drive. No odour with characteristics matching 'burnt' or 'smoke' were detected during the southern boundary survey on the same day.

It is unclear if the odour detection on 9th September; 'smoke' with an intensity of '4', was a result of the landfill hotspot, or another source. The odour assessor noted a haze associated with burning vegetation in the surrounding area on that day. Based on WSP Golder's experience, odour intensities below '3 – distinct', are less likely to cause annoyance and result in complaints. Only one location, during all boundary and residential surveys, was found to have an odour intensity of '3' or above and characteristic matching 'burnt' or 'smoke'. To aid in identifying the source of any potential future 'burnt' odours, on-going odour surveys conducted by suitably trained staff could be implemented.

9.0 IMPORTANT INFORMATION

Your attention is drawn to the document "Important Information Relating to this Document", which is included in Appendix B. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Golder, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

Signature Page

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APPENDIX A

VOC Results

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1853**	**22-1854**	**22-1855**
Start date	**5/09/2022**	**5/09/2022**	**5/09/2022**
End date	**6/09/2022**	**6/09/2022**	**6/09/2022**
Compound	**Concentration (µg/m^3)**		
Acrolein	<3.6	<3.5	<3.3
Acrylonitrile	<9.2	<8.9	<8.6
tert-Amyl Methyl Ether	<3.1	<3	<2.9
Benzene	<2.6	<2.5	<2.4
Bromodichloromethane	<5.1	<4.9	<4.8
Bromoform	<6.1	<5.9	<5.7
Bromomethane	<4.6	<4.4	<4.3
1,3-Butadiene	<1.5	<1.5	<1.4
2-Butanone (Methyl Ethyl Ketone)	**17**	**15**	**16**
tert-Butyl Alcohol	<2.6	<2.5	<2.4
n-Butylbenzene	<4.1	<3.9	<3.8
sec-Butylbenzene	<4.1	<3.9	<3.8
tert-Butylbenzene	<4.1	<3.9	<3.8
Carbon Tetrachloride	<5.1	<4.9	<4.8
Chlorobenzene	<3.1	<3	<2.9
Chloroethane	<3.1	<3	<2.9
Chloroform	<4.6	<4.4	<4.3
Chloromethane	<3.6	<3.5	<3.3
2-Chloroprene	<5.6	<5.4	<5.3
3-Chloropropene	<3.6	<3.5	<3.3
2-Chlorotoluene	<4.6	<4.4	<4.3
alpha-Chlorotoluene	<3.6	<3.5	<3.3
Cumene	<4.1	<3.9	<3.8
Cyclohexane	<2	<2	**2.9**
o-Cymene	<4.1	<3.9	<3.8
Dibromochloromethane	<6.1	<5.9	<5.7
1,2-Dibromoethane (EDB)	<6.1	<5.9	<5.7
1,2-Dichlorobenzene	<6.6	<6.4	<6.2
1,3-Dichlorobenzene	<6.6	<6.4	<6.2
1,4-Dichlorobenzene	<6.6	<6.4	<6.2
1,1-Dichloroethane	<3.6	<3.5	<3.3
1,2-Dichloroethane	<5.1	<4.9	<4.8
1,1-Dichloroethene	<3.1	<3	<2.9
cis-1,2-Dichloroethene	<4.1	<3.9	<3.8
trans-1,2-Dichloroethene	<3.1	<3	<2.9
1,2-Dichloropropane	<9.2	<8.9	<8.6
cis-1,3-Dichloropropene	<3.1	<3	<2.9
trans-1,3-Dichloropropene	<3.6	<3.5	<3.3
Diisopropyl Ether	<3.6	<3.5	<3.3
1,4-Dioxane	<3.1	<3	<2.9
Ethyl Acetate	<4.1	<3.9	<3.8
Ethyl Benzene	<3.1	<3	<2.9
Ethyl tert-Butyl Ether	<2.6	<2.5	<2.4
4-Ethyltoluene	<3.1	<3	<2.9

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1853**	**22-1854**	**22-1855**
Start date	**5/09/2022**	**5/09/2022**	**5/09/2022**
End date	**6/09/2022**	**6/09/2022**	**6/09/2022**
Compound	**Concentration (µg/m^3)**		
Freon 11	<1.5	<1.5	<1.4
Freon 113	<5.1	<4.9	<4.8
Freon 114	<1.5	<1.5	<1.4
Freon 12	**2.7**	**2.6**	**2.5**
Heptane	<3.6	<3.5	<3.3
Hexachlorobutadiene	<10	<9.9	<9.5
Hexane	<3.1	<3	<2.9
2-Hexanone	<3.1	<3	<2.9
m,p-Xylene	<6.6	<6.4	<6.2
Methyl Methacrylate	<3.6	<3.5	<3.3
Methyl tert-butyl ether	<3.1	<3	<2.9
4-Methyl-2-pentanone	<3.1	<3	<2.9
Naphthalene	<11	<10	<10
2-Propanol	<51	<49	<48
Propene	<5.1	<4.9	<4.8
Propylbenzene	<3.6	<3.5	<3.3
Styrene	<3.1	<3	<2.9
1,1,1,2-Tetrachloroethane	<5.1	<4.9	<4.8
1,1,2,2-Tetrachloroethane	<3.6	<3.5	<3.3
Tetrachloroethene	<5.6	<5.4	<5.3
Tetrahydrofuran	<2	<2	<1.9
Toluene	<3.1	<3	<2.9
1,2,4-Trichlorobenzene	<18	<18	<17
1,1,1-Trichloroethane	<4.1	<3.9	<3.8
1,1,2-Trichloroethane	<4.1	<3.9	<3.8
Trichloroethene	<4.6	<4.4	<4.3
1,2,4-Trimethylbenzene	<4.1	<3.9	<3.8
1,3,5-Trimethylbenzene	<3.1	<3	<2.9
2,2,4-Trimethylpentane	<4.6	<4.4	<4.3
Vinyl Acetate	<3.6	<3.5	<3.3
Vinyl Bromide	<4.1	<3.9	<3.8
Vinyl Chloride	<2	<2	<1.9
o-Xylene	<3.1	<3	<2.9
Xylenes	<6.6	<6.4	<6.2
Hydrogen Sulphide	<0.1	<0.1	<0.1
Carbonyl Sulphide	<0.1	<0.1	<0.1
Methyl Mercaptan	<0.1	<0.1	<0.1
Ethyl Mercaptan	<0.1	<0.1	<0.1
Dimethyl Sulfide	<0.1	<0.1	<0.1
n-Propyl Mercaptan	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1
n-Butyl Mercaptan	<0.1	<0.1	<0.1
Tetrahydrothiophene	<0.1	<0.1	<0.1

Results expressed as micrograms per cubic metre of air at 0°C and 101.325 kPa
Analysis conducted by SGS (NATA Laboratory Accreditation Number 2562).

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1853**	**22-1854**	**22-1855**
Start date	**5/09/2022**	**5/09/2022**	**5/09/2022**
End date	**6/09/2022**	**6/09/2022**	**6/09/2022**
Compound	**Concentration (µg/m^3)**		

Analysis conducted on 27/09/2022, Report No. 10070739

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1856**	**22-1857**	**22-1859**
Start date	**6/09/2022**	**6/09/2022**	**6/09/2022**
End date	**7/09/2022**	**7/09/2022**	**7/09/2022**
Compound	**Concentration (µg/m^3)**		
Acrolein	<3.2	<3.4	<3.6
Acrylonitrile	<8.3	<8.8	<9.2
tert-Amyl Methyl Ether	<2.8	<2.9	<3.1
Benzene	<2.3	<2.5	<2.6
Bromodichloromethane	<4.6	<4.9	<5.1
Bromoform	<5.6	<5.9	<6.2
Bromomethane	<4.2	<4.4	<4.6
1,3-Butadiene	<1.4	<1.5	<1.5
2-Butanone (Methyl Ethyl Ketone)	**7.7**	**6.5**	**6.1**
tert-Butyl Alcohol	<2.3	<2.5	<2.6
n-Butylbenzene	<3.7	<3.9	<4.1
sec-Butylbenzene	<3.7	<3.9	<4.1
tert-Butylbenzene	<3.7	<3.9	<4.1
Carbon Tetrachloride	<4.6	<4.9	<5.1
Chlorobenzene	<2.8	<2.9	<3.1
Chloroethane	<2.8	<2.9	<3.1
Chloroform	<4.2	<4.4	<4.6
Chloromethane	<3.2	<3.4	<3.6
2-Chloroprene	<5.1	<5.4	<5.6
3-Chloropropene	<3.2	<3.4	<3.6
2-Chlorotoluene	<4.2	<4.4	<4.6
alpha-Chlorotoluene	<3.2	<3.4	<3.6
Cumene	<3.7	<3.9	<4.1
Cyclohexane	<1.9	<2	<2.1
o-Cymene	<3.7	<3.9	<4.1
Dibromochloromethane	<5.6	<5.9	<6.2
1,2-Dibromoethane (EDB)	<5.6	<5.9	<6.2
1,2-Dichlorobenzene	<6	<6.4	<6.7
1,3-Dichlorobenzene	<6	<6.4	<6.7
1,4-Dichlorobenzene	<6	<6.4	<6.7
1,1-Dichloroethane	<3.2	<3.4	<3.6
1,2-Dichloroethane	<4.6	<4.9	<5.1
1,1-Dichloroethene	<2.8	<2.9	<3.1
cis-1,2-Dichloroethene	<3.7	<3.9	<4.1
trans-1,2-Dichloroethene	<2.8	<2.9	<3.1
1,2-Dichloropropane	<8.3	<8.8	<9.2
cis-1,3-Dichloropropene	<2.8	<2.9	<3.1
trans-1,3-Dichloropropene	<3.2	<3.4	<3.6
Diisopropyl Ether	<3.2	<3.4	<3.6
1,4-Dioxane	<2.8	<2.9	<3.1
Ethyl Acetate	<3.7	<3.9	<4.1
Ethyl Benzene	<2.8	<2.9	<3.1
Ethyl tert-Butyl Ether	<2.3	<2.5	<2.6
4-Ethyltoluene	<2.8	<2.9	<3.1

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1856**	**22-1857**	**22-1859**
Start date	**6/09/2022**	**6/09/2022**	**6/09/2022**
End date	**7/09/2022**	**7/09/2022**	**7/09/2022**
Compound	**Concentration (µg/m^3)**		
Freon 11	<1.4	<1.5	<1.5
Freon 113	<4.6	<4.9	<5.1
Freon 114	<1.4	<1.5	<1.5
Freon 12	**2.5**	**2.6**	**2.5**
Heptane	<3.2	<3.4	<3.6
Hexachlorobutadiene	<9.3	<9.8	<10
Hexane	<2.8	<2.9	<3.1
2-Hexanone	<2.8	<2.9	<3.1
m,p-Xylene	<6	<6.4	<6.7
Methyl Methacrylate	<3.2	<3.4	<3.6
Methyl tert-butyl ether	<2.8	<2.9	<3.1
4-Methyl-2-pentanone	<2.8	<2.9	<3.1
Naphthalene	<9.7	<10	<11
2-Propanol	<46	<49	<51
Propene	<4.6	<4.9	<5.1
Propylbenzene	<3.2	<3.4	<3.6
Styrene	<2.8	<2.9	<3.1
1,1,1,2-Tetrachloroethane	<4.6	<4.9	<5.1
1,1,2,2-Tetrachloroethane	<3.2	<3.4	<3.6
Tetrachloroethene	<5.1	<5.4	<5.6
Tetrahydrofuran	<1.9	<2	<2.1
Toluene	<2.8	<2.9	<3.1
1,2,4-Trichlorobenzene	<17	<18	<18
1,1,1-Trichloroethane	<3.7	<3.9	<4.1
1,1,2-Trichloroethane	<3.7	<3.9	<4.1
Trichloroethene	<4.2	<4.4	<4.6
1,2,4-Trimethylbenzene	<3.7	<3.9	<4.1
1,3,5-Trimethylbenzene	<2.8	<2.9	<3.1
2,2,4-Trimethylpentane	<4.2	<4.4	<4.6
Vinyl Acetate	<3.2	<3.4	<3.6
Vinyl Bromide	<3.7	<3.9	<4.1
Vinyl Chloride	<1.9	<2	<2.1
o-Xylene	<2.8	<2.9	<3.1
Xylenes	<6	<6.4	<6.7
Hydrogen Sulphide	<0.1	<0.1	<0.1
Carbonyl Sulphide	<0.1	<0.1	<0.1
Methyl Mercaptan	<0.1	<0.1	<0.1
Ethyl Mercaptan	<0.1	<0.1	<0.1
Dimethyl Sulfide	<0.1	<0.1	<0.1
n-Propyl Mercaptan	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1
n-Butyl Mercaptan	<0.1	<0.1	<0.1
Tetrahydrothiophene	<0.1	<0.1	<0.1

Results expressed as micrograms per cubic metre of air
Analysis conducted by SGS (NATA Laboratory Accredit

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	22-1856	22-1857	22-1859
Start date	6/09/2022	6/09/2022	6/09/2022
End date	7/09/2022	7/09/2022	7/09/2022
Compound	**Concentration (µg/m^3)**		
Analysis conducted on 27/09/2022, Report No. 1007073			

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1860**	**22-1861**	**22-1862**
Start date	**7/09/2022**	**7/09/2022**	**7/09/2022**
End date	**8/09/2022**	**8/09/2022**	**8/09/2022**
Compound	**Concentration (µg/m^3)**		
Acrolein	<3.4	<3.1	<3.5
Acrylonitrile	<8.8	<8	<9
tert-Amyl Methyl Ether	<2.9	<2.7	<3
Benzene	<2.4	<2.2	<2.5
Bromodichloromethane	<4.9	<4.4	<5
Bromoform	<5.9	<5.3	<6
Bromomethane	<4.4	<4	<4.5
1,3-Butadiene	<1.5	<1.3	<1.5
2-Butanone (Methyl Ethyl Ketone)	**6.1**	**5**	**5.7**
tert-Butyl Alcohol	<2.4	<2.2	<2.5
n-Butylbenzene	<3.9	<3.6	<4
sec-Butylbenzene	<3.9	<3.6	<4
tert-Butylbenzene	<3.9	<3.6	<4
Carbon Tetrachloride	<4.9	<4.4	<5
Chlorobenzene	<2.9	<2.7	<3
Chloroethane	<2.9	<2.7	<3
Chloroform	<4.4	<4	<4.5
Chloromethane	<3.4	<3.1	<3.5
2-Chloroprene	<5.4	<4.9	<5.5
3-Chloropropene	<3.4	<3.1	<3.5
2-Chlorotoluene	<4.4	<4	<4.5
alpha-Chlorotoluene	<3.4	<3.1	<3.5
Cumene	<3.9	<3.6	<4
Cyclohexane	<2	<1.8	<2
o-Cymene	<3.9	<3.6	<4
Dibromochloromethane	<5.9	<5.3	<6
1,2-Dibromoethane (EDB)	<5.9	<5.3	<6
1,2-Dichlorobenzene	<6.4	<5.8	<6.5
1,3-Dichlorobenzene	<6.4	<5.8	<6.5
1,4-Dichlorobenzene	<6.4	<5.8	<6.5
1,1-Dichloroethane	<3.4	<3.1	<3.5
1,2-Dichloroethane	<4.9	<4.4	<5
1,1-Dichloroethene	<2.9	<2.7	<3
cis-1,2-Dichloroethene	<3.9	<3.6	<4
trans-1,2-Dichloroethene	<2.9	<2.7	<3
1,2-Dichloropropane	<8.8	<8	<9
cis-1,3-Dichloropropene	<2.9	<2.7	<3
trans-1,3-Dichloropropene	<3.4	<3.1	<3.5
Diisopropyl Ether	<3.4	<3.1	<3.5
1,4-Dioxane	<2.9	<2.7	<3
Ethyl Acetate	<3.9	<3.6	<4
Ethyl Benzene	<2.9	<2.7	<3
Ethyl tert-Butyl Ether	<2.4	<2.2	<2.5
4-Ethyltoluene	<2.9	<2.7	<3

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1860**	**22-1861**	**22-1862**
Start date	**7/09/2022**	**7/09/2022**	**7/09/2022**
End date	**8/09/2022**	**8/09/2022**	**8/09/2022**
Compound	**Concentration (µg/m^3)**		
Freon 11	<1.5	<1.3	<1.5
Freon 113	<4.9	<4.4	<5
Freon 114	<1.5	<1.3	<1.5
Freon 12	**2.5**	**2.5**	**2.6**
Heptane	<3.4	<3.1	<3.5
Hexachlorobutadiene	<9.8	<8.9	<10
Hexane	<2.9	<2.7	<3
2-Hexanone	<2.9	<2.7	<3
m,p-Xylene	<6.4	<5.8	<6.5
Methyl Methacrylate	<3.4	<3.1	<3.5
Methyl tert-butyl ether	<2.9	<2.7	<3
4-Methyl-2-pentanone	<2.9	<2.7	<3
Naphthalene	<10	<9.3	<11
2-Propanol	<49	<44	<50
Propene	<4.9	<4.4	<5
Propylbenzene	<3.4	<3.1	<3.5
Styrene	<2.9	<2.7	<3
1,1,1,2-Tetrachloroethane	<4.9	<4.4	<5
1,1,2,2-Tetrachloroethane	<3.4	<3.1	<3.5
Tetrachloroethene	<5.4	<4.9	<5.5
Tetrahydrofuran	<2	<1.8	<2
Toluene	<2.9	<2.7	<3
1,2,4-Trichlorobenzene	<18	<16	<18
1,1,1-Trichloroethane	<3.9	<3.6	<4
1,1,2-Trichloroethane	<3.9	<3.6	<4
Trichloroethene	<4.4	<4	<4.5
1,2,4-Trimethylbenzene	<3.9	<3.6	<4
1,3,5-Trimethylbenzene	<2.9	<2.7	<3
2,2,4-Trimethylpentane	<4.4	<4	<4.5
Vinyl Acetate	<3.4	<3.1	<3.5
Vinyl Bromide	<3.9	<3.6	<4
Vinyl Chloride	<2	<1.8	<2
o-Xylene	<2.9	<2.7	<3
Xylenes	<6.4	<5.8	<6.5
Hydrogen Sulphide	<0.1	<0.1	<0.1
Carbonyl Sulphide	<0.1	<0.1	<0.1
Methyl Mercaptan	<0.1	<0.1	<0.1
Ethyl Mercaptan	<0.1	<0.1	<0.1
Dimethyl Sulfide	<0.1	<0.1	<0.1
n-Propyl Mercaptan	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1
n-Butyl Mercaptan	<0.1	<0.1	<0.1
Tetrahydrothiophene	<0.1	<0.1	<0.1

Results expressed as micrograms per cubic metre of air
Analysis conducted by SGS (NATA Laboratory Accredit

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1860**	**22-1861**	**22-1862**
Start date	**7/09/2022**	**7/09/2022**	**7/09/2022**
End date	**8/09/2022**	**8/09/2022**	**8/09/2022**
Compound	**Concentration (µg/m^3)**		
Analysis conducted on 27/09/2022, Report No. 1007073			

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1863**	**22-1864**	**22-1865**
Start date	**8/09/2022**	**8/09/2022**	**8/09/2022**
End date	**9/09/2022**	**9/09/2022**	**9/09/2022**
Compound	**Concentration (µg/m^3)**		
Acrolein	<3.3	<3.4	<3.8
Acrylonitrile	<8.4	<8.7	<9.9
tert-Amyl Methyl Ether	<2.8	<2.9	<3.3
Benzene	<2.3	<2.4	<2.7
Bromodichloromethane	<4.7	<4.9	<5.5
Bromoform	<5.6	<5.8	<6.6
Bromomethane	<4.2	<4.4	<4.9
1,3-Butadiene	<1.4	<1.5	<1.6
2-Butanone (Methyl Ethyl Ketone)	**6**	**5.7**	**5.5**
tert-Butyl Alcohol	<2.3	<2.4	<2.7
n-Butylbenzene	<3.7	<3.9	<4.4
sec-Butylbenzene	<3.7	<3.9	<4.4
tert-Butylbenzene	<3.7	<3.9	<4.4
Carbon Tetrachloride	<4.7	<4.9	<5.5
Chlorobenzene	<2.8	<2.9	<3.3
Chloroethane	<2.8	<2.9	<3.3
Chloroform	<4.2	<4.4	<4.9
Chloromethane	<3.3	<3.4	<3.8
2-Chloroprene	<5.1	<5.3	<6
3-Chloropropene	<3.3	<3.4	<3.8
2-Chlorotoluene	<4.2	<4.4	<4.9
alpha-Chlorotoluene	<3.3	<3.4	<3.8
Cumene	<3.7	<3.9	<4.4
Cyclohexane	<1.9	<1.9	<2.2
o-Cymene	<3.7	<3.9	<4.4
Dibromochloromethane	<5.6	<5.8	<6.6
1,2-Dibromoethane (EDB)	<5.6	<5.8	<6.6
1,2-Dichlorobenzene	<6	<6.3	<7.1
1,3-Dichlorobenzene	<6	<6.3	<7.1
1,4-Dichlorobenzene	<6	<6.3	<7.1
1,1-Dichloroethane	<3.3	<3.4	<3.8
1,2-Dichloroethane	<4.7	<4.9	<5.5
1,1-Dichloroethene	<2.8	<2.9	<3.3
cis-1,2-Dichloroethene	<3.7	<3.9	<4.4
trans-1,2-Dichloroethene	<2.8	<2.9	<3.3
1,2-Dichloropropane	<8.4	<8.7	<9.9
cis-1,3-Dichloropropene	<2.8	<2.9	<3.3
trans-1,3-Dichloropropene	<3.3	<3.4	<3.8
Diisopropyl Ether	<3.3	<3.4	<3.8
1,4-Dioxane	<2.8	<2.9	<3.3
Ethyl Acetate	<3.7	<3.9	<4.4
Ethyl Benzene	<2.8	<2.9	<3.3
Ethyl tert-Butyl Ether	<2.3	<2.4	<2.7
4-Ethyltoluene	<2.8	<2.9	<3.3

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1863**	**22-1864**	**22-1865**
Start date	**8/09/2022**	**8/09/2022**	**8/09/2022**
End date	**9/09/2022**	**9/09/2022**	**9/09/2022**
Compound	**Concentration (µg/m^3)**		
Freon 11	<1.4	<1.5	<1.6
Freon 113	<4.7	<4.9	<5.5
Freon 114	<1.4	<1.5	<1.6
Freon 12	**2.6**	**2.7**	**2.5**
Heptane	<3.3	<3.4	<3.8
Hexachlorobutadiene	<9.3	<9.7	<11
Hexane	<2.8	<2.9	<3.3
2-Hexanone	<2.8	<2.9	<3.3
m,p-Xylene	<6	<6.3	<7.1
Methyl Methacrylate	<3.3	<3.4	<3.8
Methyl tert-butyl ether	<2.8	<2.9	<3.3
4-Methyl-2-pentanone	<2.8	<2.9	<3.3
Naphthalene	<9.8	<10	<12
2-Propanol	<47	<49	<55
Propene	<4.7	<4.9	<5.5
Propylbenzene	<3.3	<3.4	<3.8
Styrene	<2.8	<2.9	<3.3
1,1,1,2-Tetrachloroethane	<4.7	<4.9	<5.5
1,1,2,2-Tetrachloroethane	<3.3	<3.4	<3.8
Tetrachloroethene	<5.1	<5.3	<6
Tetrahydrofuran	<1.9	<1.9	<2.2
Toluene	<2.8	<2.9	<3.3
1,2,4-Trichlorobenzene	<17	<17	<20
1,1,1-Trichloroethane	<3.7	<3.9	<4.4
1,1,2-Trichloroethane	<3.7	<3.9	<4.4
Trichloroethene	<4.2	<4.4	<4.9
1,2,4-Trimethylbenzene	<3.7	<3.9	<4.4
1,3,5-Trimethylbenzene	<2.8	<2.9	<3.3
2,2,4-Trimethylpentane	<4.2	<4.4	<4.9
Vinyl Acetate	<3.3	<3.4	<3.8
Vinyl Bromide	<3.7	<3.9	<4.4
Vinyl Chloride	<1.9	<1.9	<2.2
o-Xylene	<2.8	<2.9	<3.3
Xylenes	<6	<6.3	<7.1
Hydrogen Sulphide	<0.1	<0.1	<0.1
Carbonyl Sulphide	<0.1	<0.1	<0.1
Methyl Mercaptan	<0.1	<0.1	<0.1
Ethyl Mercaptan	<0.1	<0.1	<0.1
Dimethyl Sulfide	<0.1	<0.1	<0.1
n-Propyl Mercaptan	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1
n-Butyl Mercaptan	<0.1	<0.1	<0.1
Tetrahydrothiophene	<0.1	<0.1	<0.1

Results expressed as micrograms per cubic metre of air
Analysis conducted by SGS (NATA Laboratory Accredit

Appendix A - Volatile Organic compounds

Location	Down-Wind	On Site	Up-Wind
Sample No	**22-1863**	**22-1864**	**22-1865**
Start date	**8/09/2022**	**8/09/2022**	**8/09/2022**
End date	**9/09/2022**	**9/09/2022**	**9/09/2022**
Compound	**Concentration (µg/m^3)**		
Analysis conducted on 27/09/2022, Report No. 1007073			

APPENDIX B

Important Information Relating to this Report

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The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification



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Appendix C

Water quality monitoring data

Appendix C-1
Figures

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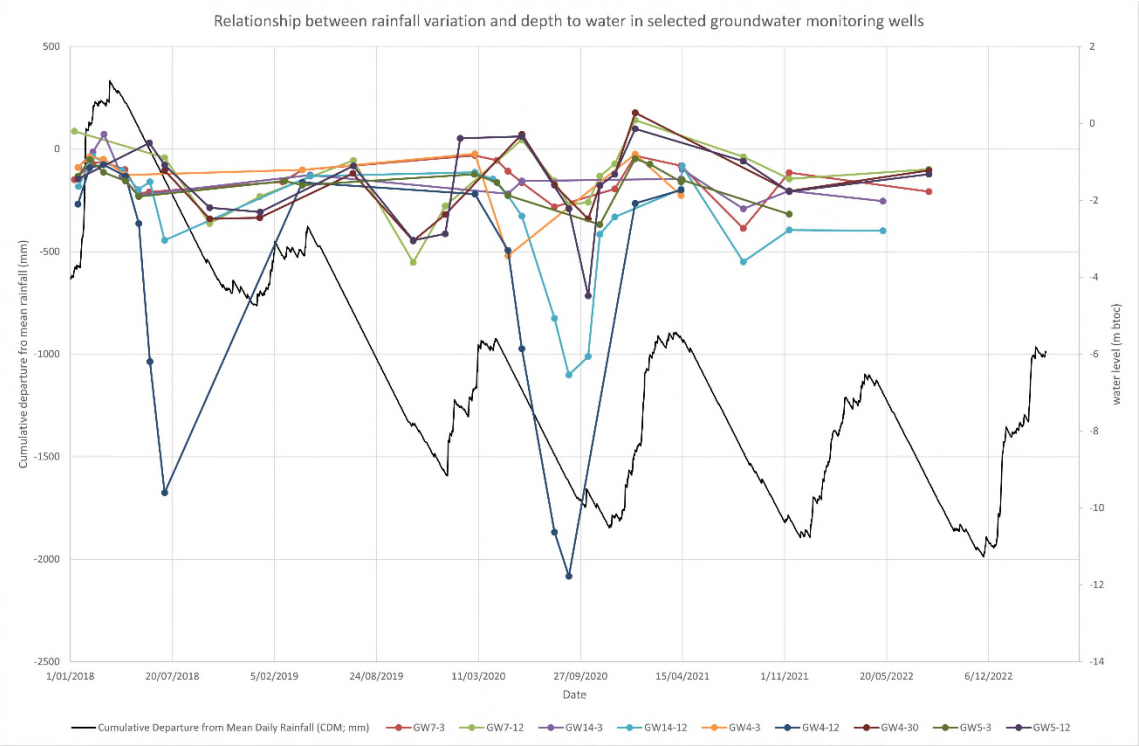


Figure C-1.1 Relationship between rainfall and cumulative departure from mean (CDM) rainfall

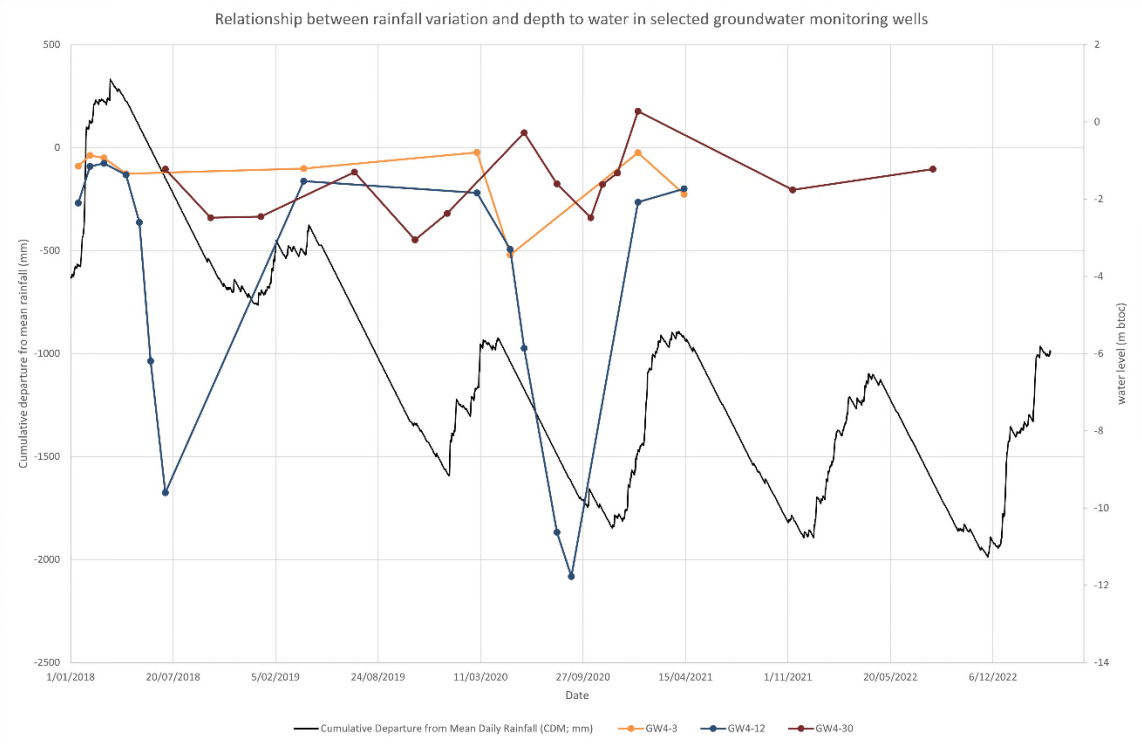


Figure C-1.2 Relationship between CDM rainfall and groundwater levels in bores at location GW4

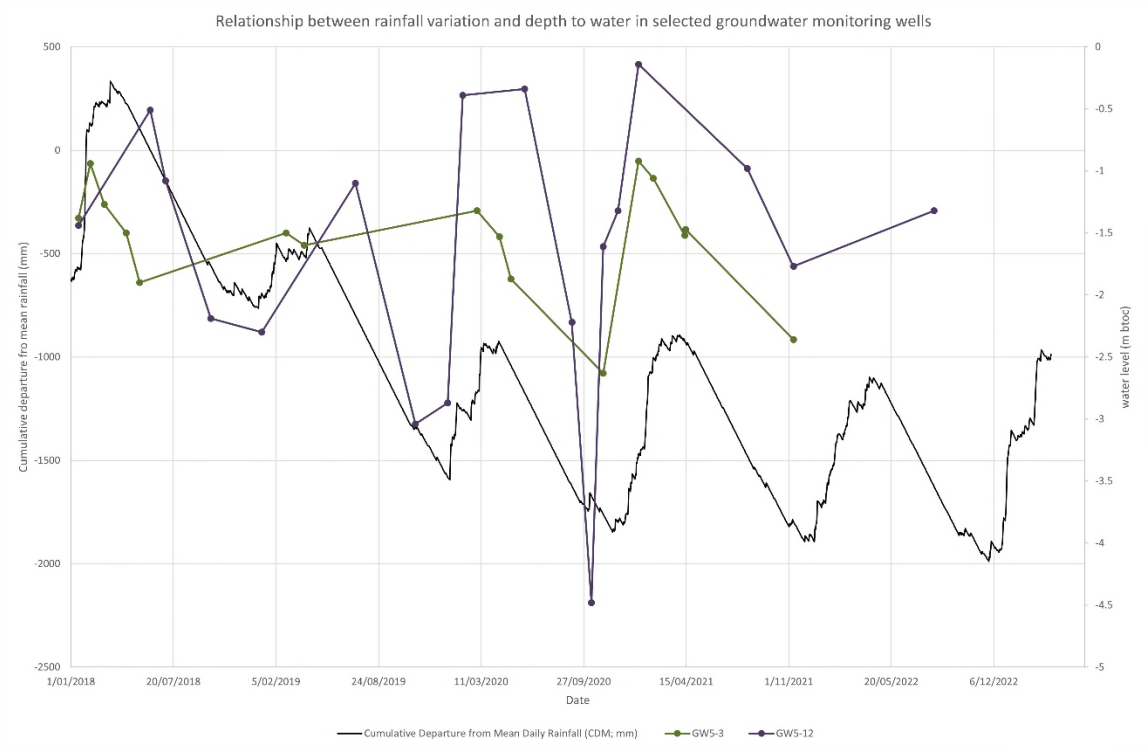


Figure C-1.3 Relationship between CDM rainfall and groundwater levels in bores at location GW5

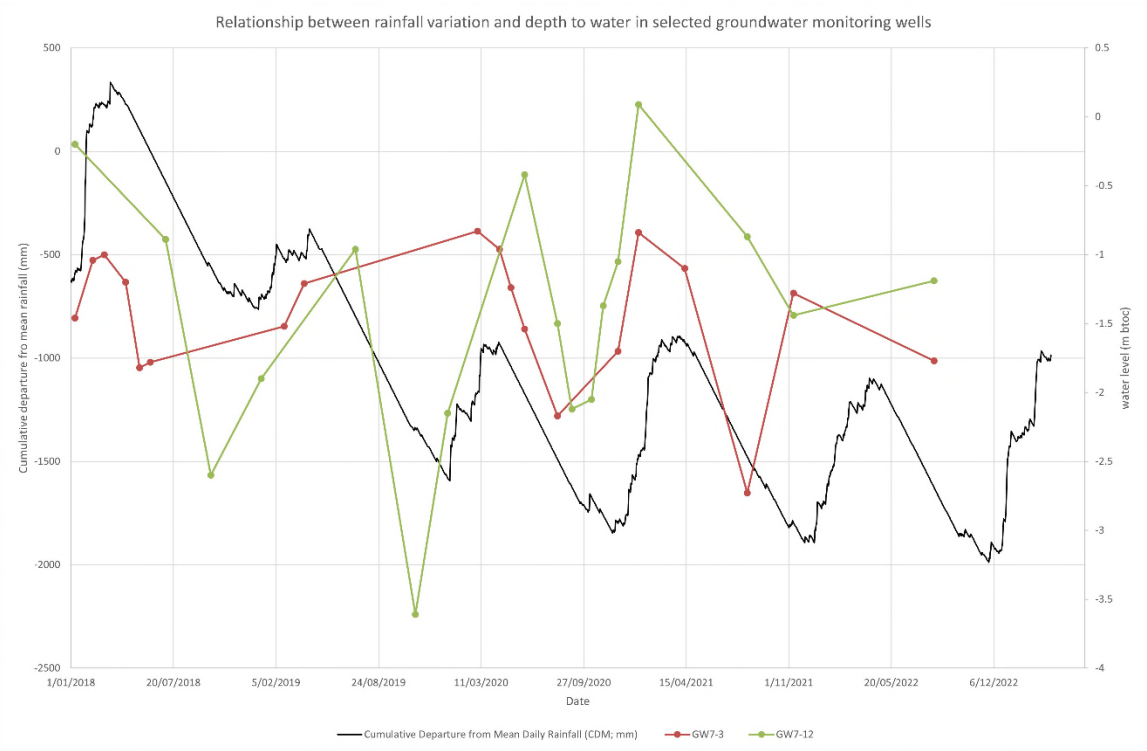


Figure C-1.4 Relationship between CDM rainfall and groundwater levels in bores at location GW7

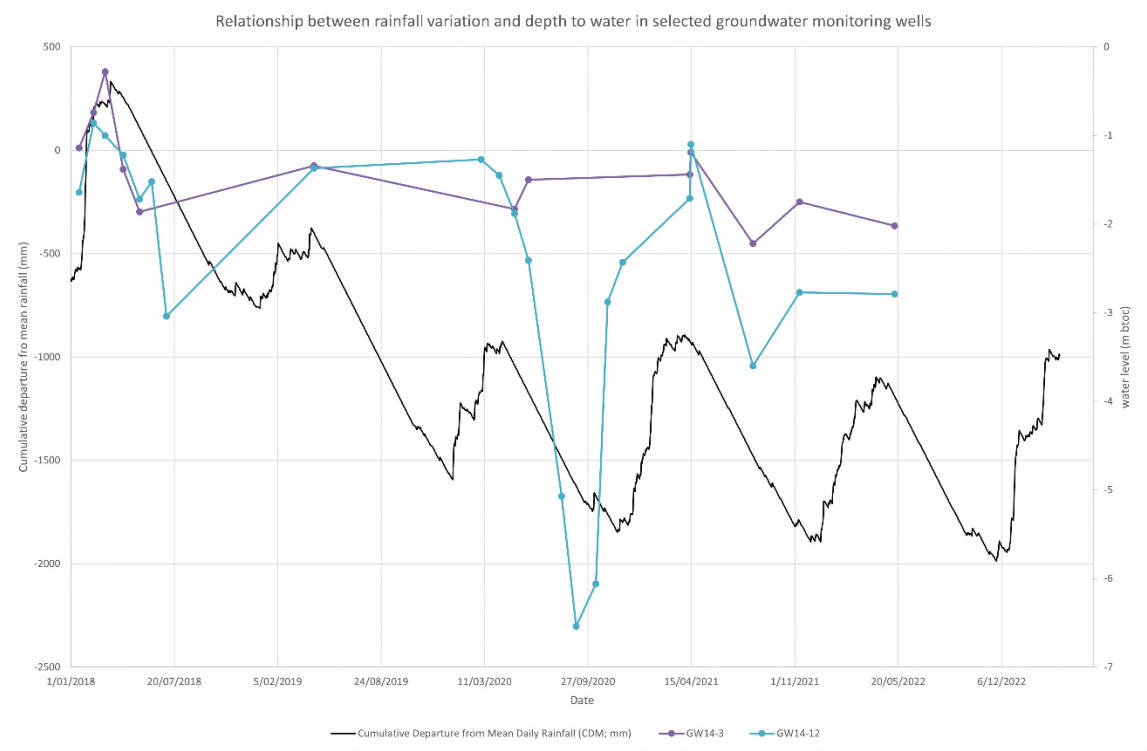


Figure C-1.5 Relationship between CDM rainfall and groundwater levels in bores at location GW14

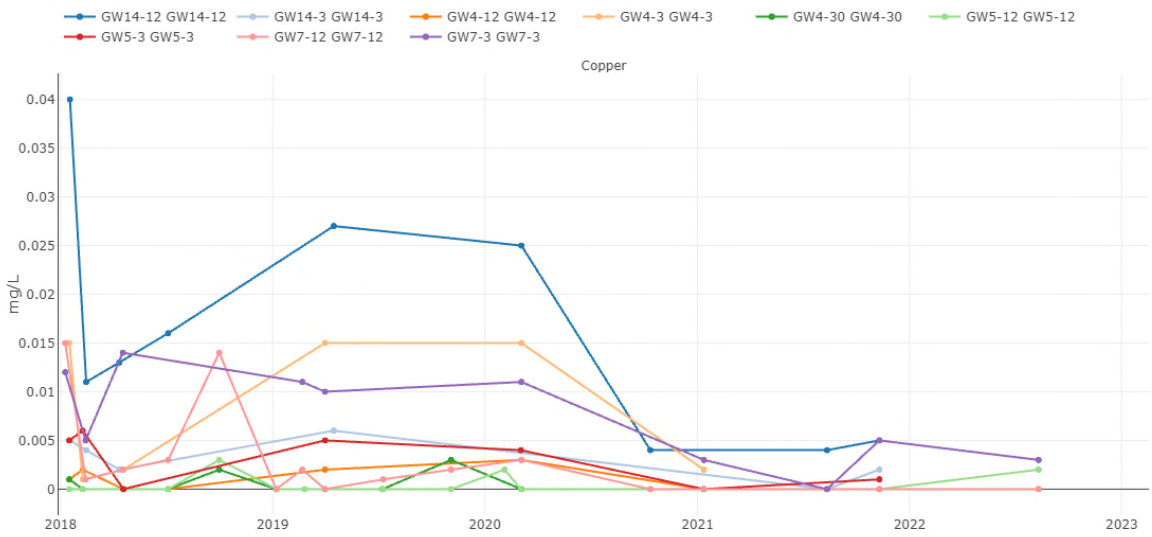


Figure C-1.6 Concentration of copper in the selected wells over the reviewed period

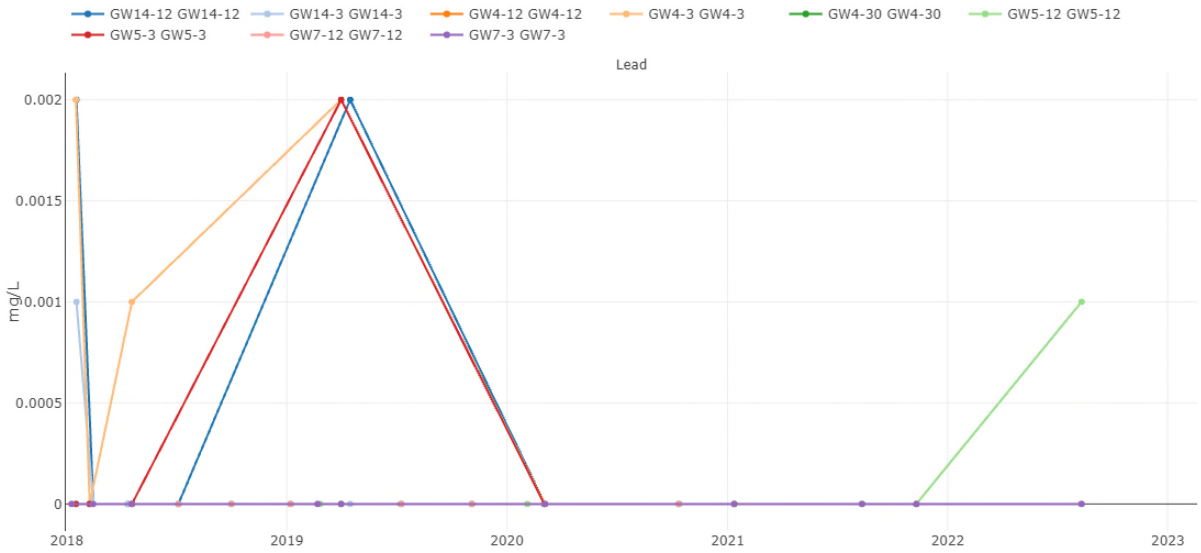


Figure C-1.7 Concentration of lead in the selected wells over the reviewed period

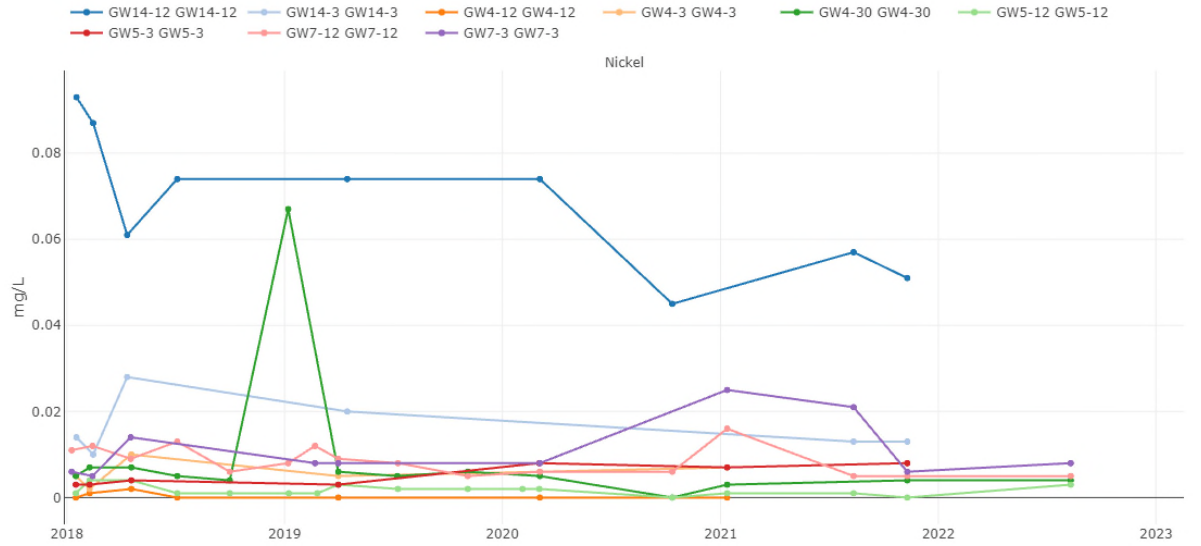


Figure C-1.8 Concentration of nickel in the selected wells over the reviewed period



Figure C-1.9 Concentration of PFAS in the selected wells over the reviewed period

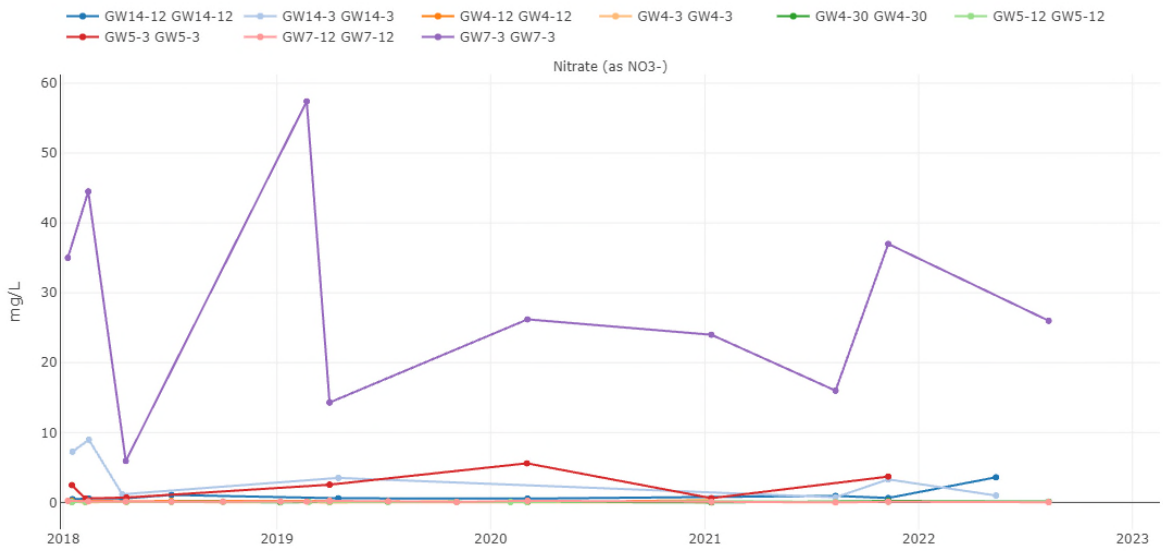


Figure C-1.10 Concentration of nitrate (as NO_3) in the selected wells over the reviewed period

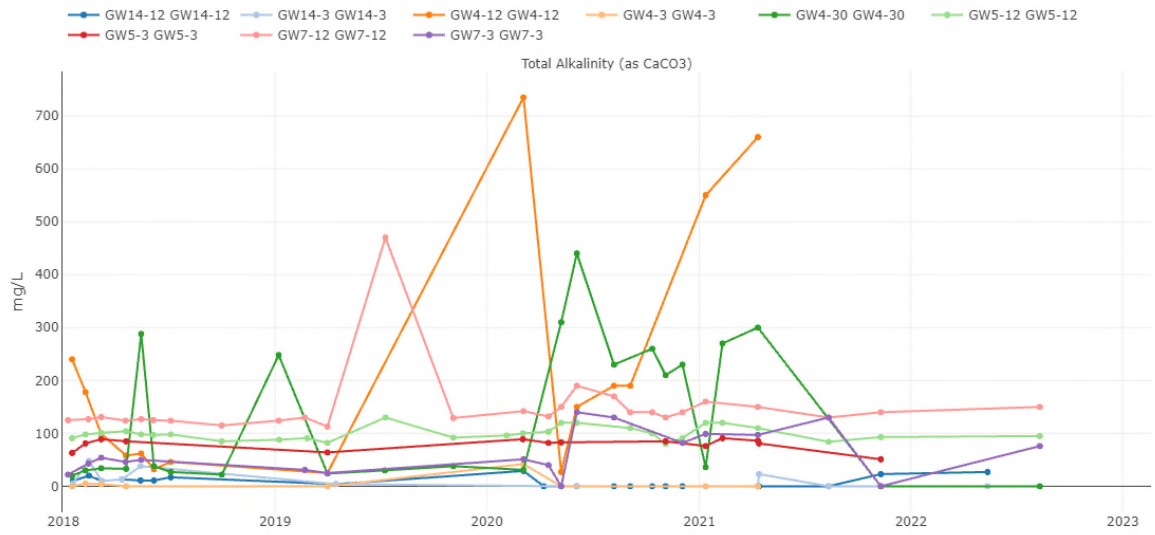


Figure C-1.11 Alkalinity (total, as $CaCO_3$) in the selected wells over the reviewed period

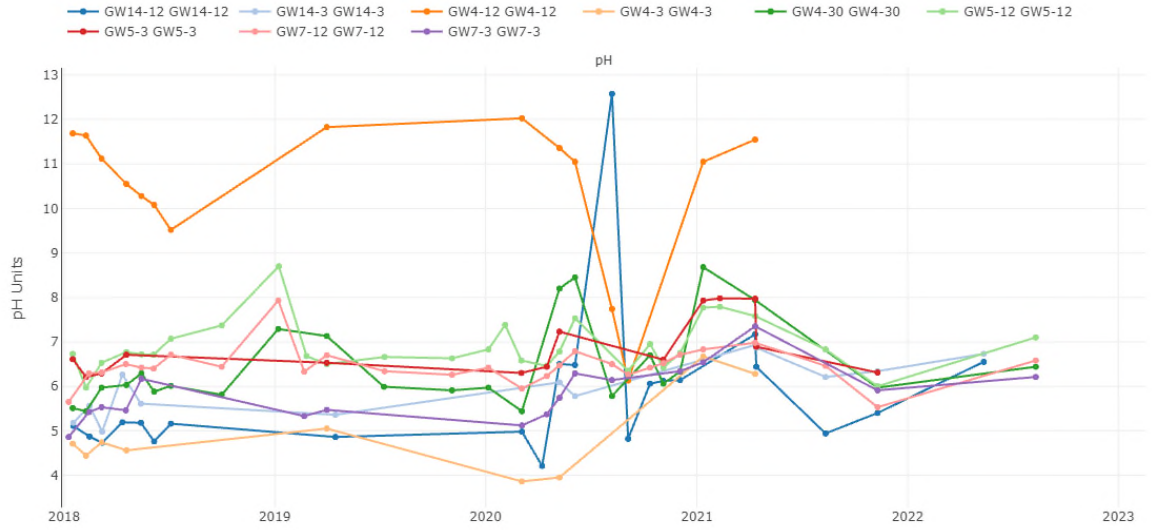


Figure C-1.12 pH in the selected wells over the reviewed period

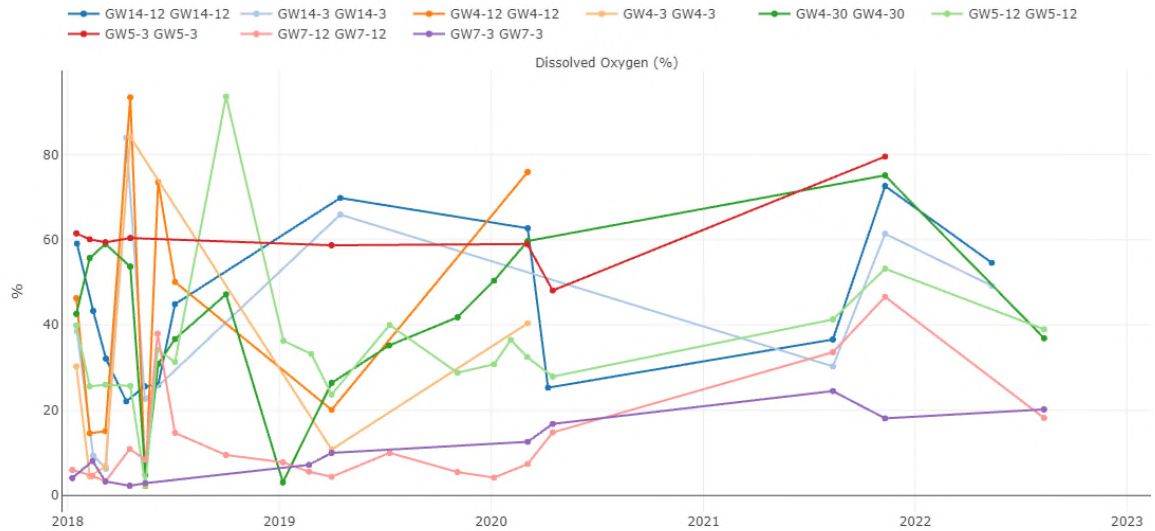


Figure C-1.13 DO Saturation % in the selected wells over the reviewed period

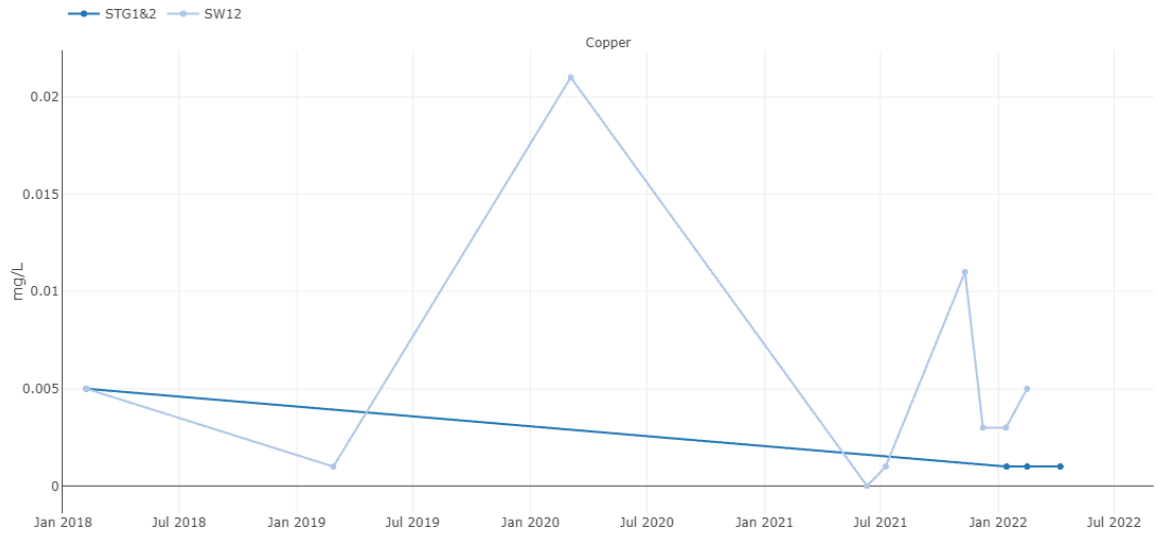


Figure C-1.14 Concentration of copper in SWSTG1&2 and SW12 over the reviewed period

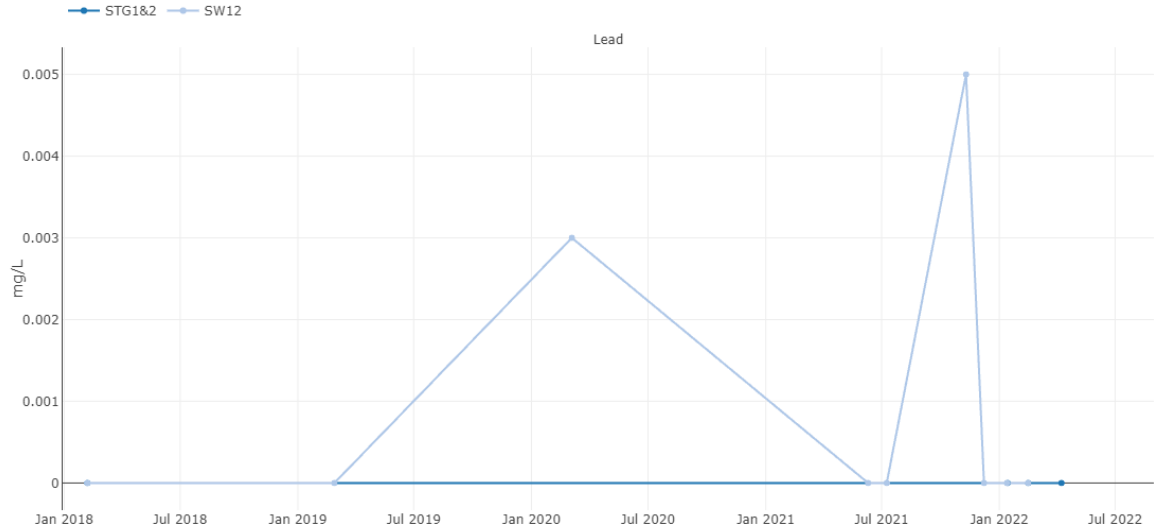


Figure C-1.15 Concentration of lead in SWSTG1&2 and SW12 over the reviewed period

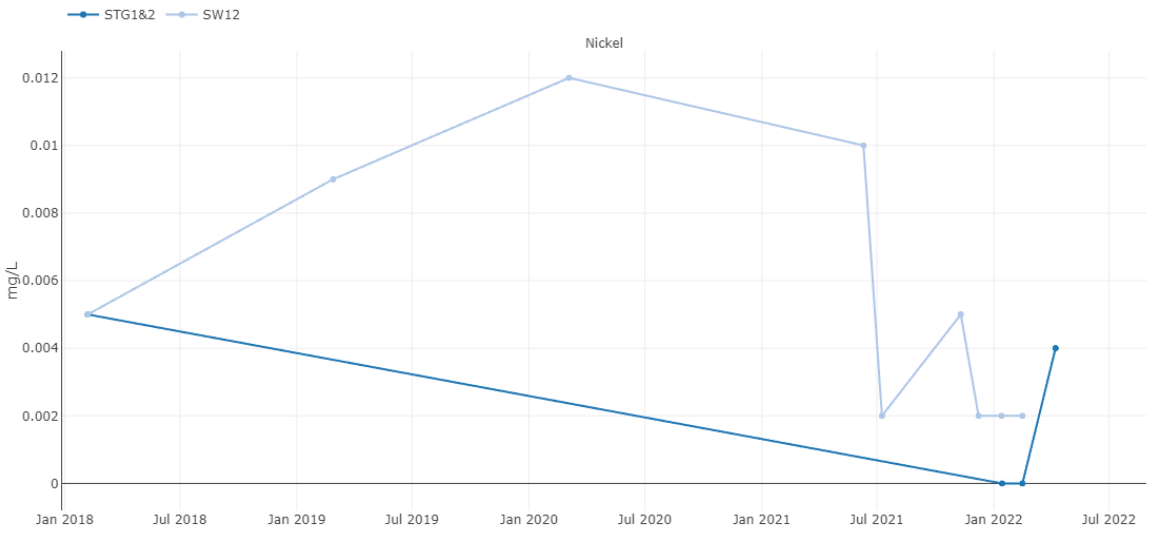


Figure C-1.16 Concentration of nickel in SWSTG1&2 and SW12 over the reviewed period

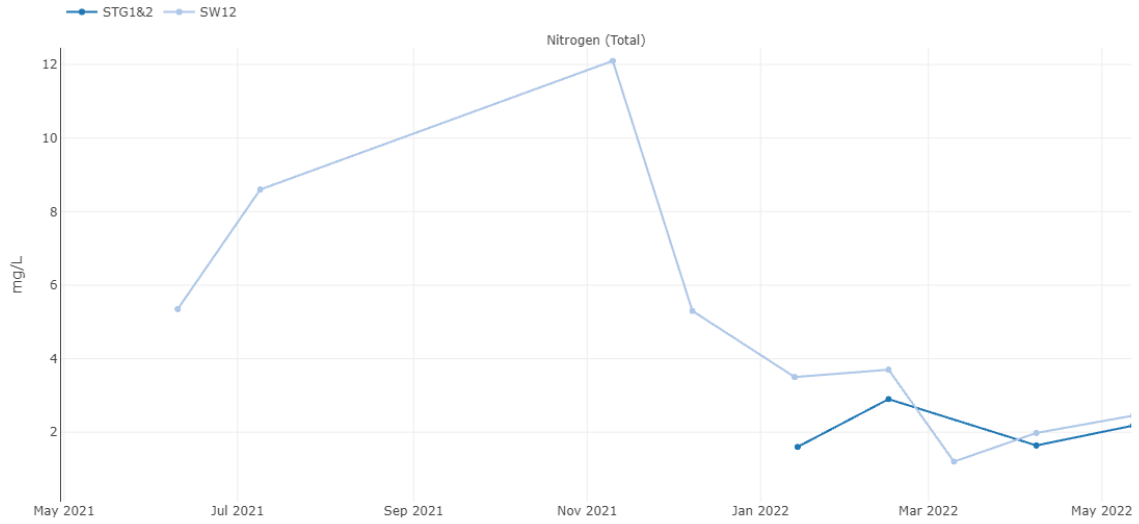


Figure C-1.17 Concentration of total nitrogen in SWSTG1&2 and SW12 over the reviewed period

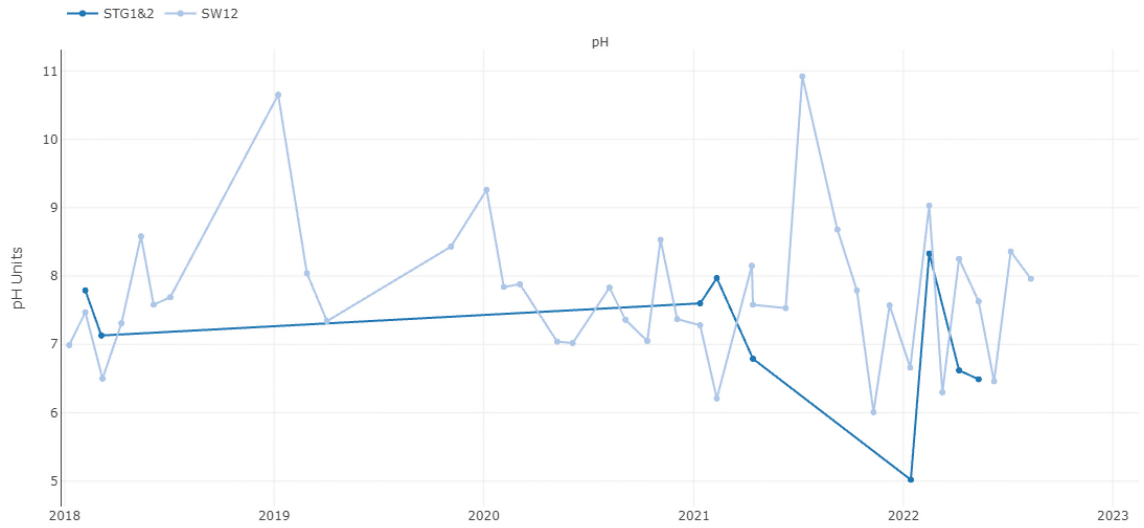


Figure C-1.18 pH in SWSTG1&2 and SW12 over the reviewed period

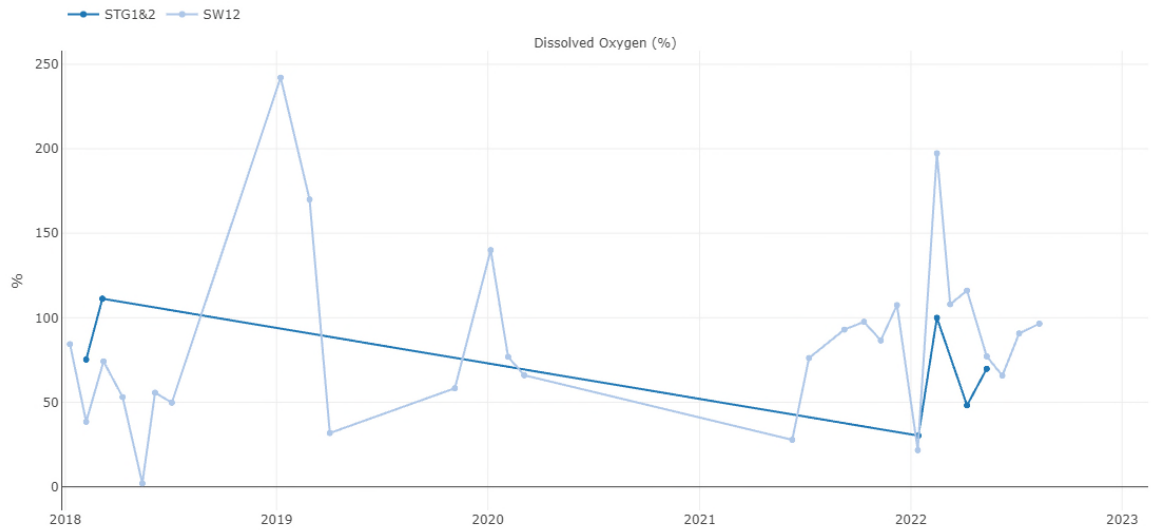


Figure C-1.19 DO saturation % in SWSTG1&2 and SW12 over the reviewed period

Appendix C-2
Analysis table

		Inorganics																			Gauging data	NA	Phenols
		Ammonium Ion	Dissolved Oxygen % Saturation (Lab)	Dissolved Oxygen (Lab)	Oxidation-Reduction Potential	Total Phosphorus as P (Organic Phosphate as P)	Ammonia as NH3	Electrical Conductivity (Non Compensated)	Temperature (Lab)	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Alkalinity (total) as CaCO3	Chloride	Nitrate (as NO3-)	Nitrite (as NO2-)	Nitrogen (Total)	Sodium	Sulphate	Total Dissolved Solids (Lab)	Turbidity (Lab)	Depth to water	Total PCBs	Total Phenols
		mg/L	%	mg/L	mV	mg/L	mg/L	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mBTOC	ug/L	µg/L
EQL																							
z/s EPL188-03 - Darwin Harbour			80-100			0.03	0.024*									0.3							
z/s EPL188-03 - Darwin Harbour (at 20 deg.C)				7.36-9.2																			
z/s EPL188-03 - ANZG (2018) Marine water 90%																							
z/s EPL188-03 - CCME Long Term Marine water														45									
z/s EPL188-03 - NEMP 2.0 2020 90% Eco Marine Water																							
z/s EPL188-03 - ANZECC 2000 Irrigation Long Term Trigger Values																5							
z/s EPL188-03 - ADWG (PCR/Aesthetic)																							
z/s EPL188-03 - ADWG (PCR/Aesthetic)														500	30								
z/s EPL188-03 - NEMP 2.0 2020 Recreational Water																							
z/s EPL188-03 - ADWG Health														50	3								
z/s EPL188-03 - NEMP 2.0 2020 Drinking Water																							
Location Code	**Date**																						
STG1&2	**06 Feb 2018**	10	75.3	-	116.6	-	10.4	1193	26.9	-	-	247	75	1.33	-	-	55	284	7700	>1,000	-	-	-
STG1&2	**06 Mar 2018**	16.8	111.3	-	115.2	-	-	1281	34.9	-	-	289	135	-	-	-	-	31	831.5	244	-	<1	<50
STG1&2	**12 Jan 2021**	-	-	4.31	11	-	0.09	210	34.1	44	<10	44	32	-	-	-	-	5.6	-	-	-	-	-
STG1&2	**10 Feb 2021**	-	-	5.22	-15	-	0.07	181	30.2	30	<10	30	31	-	-	-	-	6.3	-	-	-	-	-
STG1&2	**14 Apr 2021**	-	-	2.49	-	-	-	163.4	24.5	-	<10	22	29	-	-	-	-	13	-	-	-	-	-
STG1&2	**14 Jan 2022**	-	30.3	-	124.7	0.02	110	17888	28.9	54	<10	54	15	0.29	<0.02	1.6	16	26	-	-	8.11	-	-
STG1&2	**15 Feb 2022**	-	100	-	76.4	<0.05	200	264.9	35.8	55	<10	55	21	0.82	0.05	2.9	13	7.5	-	32.48	-	-	-
STG1&2	**08 Apr 2022**	-	48.2	-	66	0.01	710	225.6	26	140	<10	140	24	0.6	0.04	1.64	18	5.3	-	197.3	-	-	-
STG1&2	**12 May 2022**	-	69.8	-	38.5	0.03	20	50.7	28.8	40	<10	40	120	0.07	<0.02	2.18	63	7.2	-	147.8	-	-	-
SW12	**09 Jan 2018**	1.9	84.4	-	87.9	-	-	1433	36.9	-	-	85	338	-	-	-	-	76	929.5	384	-	-	-
SW12	**06 Feb 2018**	6.58	38.5	-	142.1	-	6.7	699	26.1	-	-	113	109	2.55	-	-	65	26	4350	374	-	-	-
SW12	**08 Mar 2018**	1.48	74.2	-	122.1	-	-	1556	31.4	-	-	87	292	-	-	-	157	46	1011.4	19	-	<1	<50
SW12	**10 Apr 2018**	2.09	53.1	-	157.8	-	-	1684	29	-	-	70	401	-	-	-	-	48	1020	51.9	-	-	-
SW12	**14 May 2018**	1	2	-	106.8	-	-	2326	24	-	-	152	615	-	-	-	-	55	1508	57.1	-	-	-
SW12	**05 Jun 2018**	0.31	55.7	-	-	-	-	2660	21.3	-	-	181	707	-	-	-	-	66	1729	-	-	-	-
SW12	**04 Jul 2018**	0.05	49.8	-	228.9	-	-	3318	24.6	-	-	178	720	-	-	-	-	81	2156	87.4	-	-	-
SW12	**08 Jan 2019**	0.08	242.1	-	-	-	-	3145	33	-	-	86	817	-	-	-	-	127	2033	-	-	-	-
SW12	**27 Feb 2019**	3.16	170	-	170	-	3.55	2780	34.8	-	-	206	726	<0.05	-	-	318	54	1803	-	-	-	-
SW12	**03 Apr 2019**	5.22	31.8	-	161	-	-	2475	29	-	-	141	684	-	-	-	-	68	1608	-2.3	-	-	-
SW12	**05 Nov 2019**	0.98	58.3	-	123	-	-	2207	25.2	-	-	16	647	-	-	-	-	159	1434	-	-	-	-
SW12	**06 Jan 2020**	0.28	140	-	119.4	-	-	2629	33.3	-	-	-	633	-	-	-	-	110	1709	88.4	-	-	-
SW12	**05 Feb 2020**	7.62	76.9	-	87	-	-	2391	32.7	-	-	191	618	-	-	-	-	113	1554	175	-	-	-
SW12	**04 Mar 2020**	7.33	66	-	132	-	7.7	1662	27	-	-	179	368	10.8	-	-	207	48	1079	>1,000	-	-	-
SW12	**08 May 2020**	-	-	4.96	55	-	1.2	2660	26.2	180	<10	180	700	-	-	-	400	68	1300	-	-	-	-
SW12	**04 Jun 2020**	-	-	6.62	58	-	0.1	3017	23.1	210	<10	210	800	-	-	-	-	79	-	-	-	-	-
SW12	**07 Aug 2020**	-	-	1.21	94	-	0.3	4260	23.8	300	<10	300	1900	-	-	-	-	99	-	-	-	-	-
SW12	**04 Sep 2020**	-	-	5.62	-78	-	11	13780	25.4	250	<10	250	4700	-	-	-	-	130	-	-	-	-	-
SW12	**12 Oct 2020**	-	-	1.3	15	-	-	1571	29.8	88	<10	88	280	-	-	-	-	79	-	-	-	-	-
SW12	**04 Nov 2020**	-	-	14.79	17	-	0.53	2395	33.6	170	<10	170	440	-	-	-	-	130	-	-	-	-	-
SW12	**03 Dec 2020**	-	-	3.26	-123	-	0.99	1601	29.4	94	<10	94	320	-	-	-	-	45	-	-	-	-	-
SW12	**12 Jan 2021**	-	-	2.22	56	-	1.4	1359	29.3	130	<10	130	250	-	-	-	-	68	-	-	-	-	-
SW12	**10 Feb 2021**	-	-	5.52	120	-	8.8	1033	31.2	200	<10	200	190	-	-	-	-	49	-	-	-	-	-
SW12	**12 Apr 2021**	-	-	9.15	-	-	22000	2190	27.2	240	<10	240	510	-	-	-	-	45	-	-	-	-	-
SW12	**14 Apr 2021**	-	-	3.98	-	-	-	1324	26.5	-	<10	58	300	-	-	-	-	50	-	-	-	-	-
SW12	**10 Jun 2021**	-	27.8	-	90	0.26	790	2274	27.9	180	<10	180	600	0.17	0.08	5.35	320	38	1100	-	-	<1	<10
SW12	**09 Jul 2021**	-	76.2	-	127.8	0.11	20	2982	29.7	220	17	230	820	<0.02	<0.02	8.6	320	15	1600	-	-	<1	<10
SW12	**08 Sep 2021**	-	93	-	152	-	-	5598	29.2	-	-	-	-	-	-	-	-	-	-	330.5	-	-	-
SW12	**12 Oct 2021**	-	97.6	-	34	-	-	14127	31.7	-	-	-	-	-	-	-	-	-	-	290.6	-	-	-
SW12	**10 Nov 2021**	-	86.6	-	91.9	0.04	1300	1124	29	44	<10	44	190	7.1	<0.02	12.1	99	51	-	934.6	-	-	-
SW12	**08 Dec 2021**	-	107.5	-	86.2	0.02	480	1285	29	75	<10	75	300	3.7	0.14	5.3	120	61	-	140.2	-	<5	<3
SW12	**13 Jan 2022**	-	21.7	-	184.7	0.03	210	22900	28.9	36	<10	36	190	1.1	0.13	3.5	100	65	-	-	1.43	-	-
SW12	**15 Feb 2022**	-	197.3	-	46.6	<0.05	540	649	34	<20	<10	<20	190	1.2	0.08	3.7	95	53	-	796.4	-	-	-
SW12	**10 Mar 2022**	-	108	-	42.1	0.04	200	740	31	47	<10	47	160	0.43	0.03	1.2	84	26	-	362	-	-	-
SW12	**08 Apr 2022**	-	116.1	-	48.4	0.03	360	967	28.5	93	<10	93	200	0.07	<0.02	1.98	110	27	-	576.1	-	-	-
SW12	**12 May 2022**	-	77.2	-	8.7	0.02	120	3258	32.9	75	<10	84	310	0.41	0.04	2.45	170	55	-	597.3	-	-	-
SW12	**08 Jun 2022**	-	65.8	-	80.8	-	-	1605	26.6	-	-	-	-	-	-	-	-	-	-	467	-	-	-
SW12	**07 Jul 2022**	-	90.7	-	187.6	-	-	2534	28.6	-	-	-	-	-	-	-	-	-	-	511.8	-	-	-
SW12	**11 Aug 2022**	-	96.5	-	2647	-	-	2647	29.8	-	-	-	-	-	-	-	-	-	-	486.3	-	-	-

	Inorganics																			Gauging data	NA	Phenols
	Ammonium Ion	Dissolved Oxygen % Saturation (Lab)	Dissolved Oxygen (Lab)	Oxidation-Reduction Potential	Total Phosphorus as P (Organic Phosphate as P)	Ammonia as NH3	Electrical Conductivity (Non Compensated)	Temperature (Lab)	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Alkalinity (total) as CaCO3	Chloride	Nitrate (as NO3-)	Nitrite (as NO2-)	Nitrogen (Total)	Sodium	Sulphate	Total Dissolved Solids (Lab)	Turbidity (Lab)	Depth to water	Total PCBs	Total Phenols
	mg/L	%	mg/L	mV	mg/L	mg/L	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mBTOC	ug/L	µg/L
Statistics																						
Number of Results	16	34	14	43	13	28	48	48	25	27	42	43	17	13	13	19	43	19	26	2	5	5
Minimum Detect	0.05	2	1.21	-123	0.01	0.07	50.7	21.3	30	17	16	15	0.07	0.03	1.2	13	5.3	831.5	-2.3	1.43	ND	ND
Maximum Concentration	16.8	242.1	14.79	2,647	0.26	22,000	22,900	36.9	300	17	300	4,700	10.8	0.14	12.1	400	284	7,700	>1,000	8.11	<5	<50
Average Concentration *	4.1	84	5	144	0.051	968	3,131	29	120	5.4	127	500	1.8	0.049	4	144	63	1,919	360	4.8	0.9	12
95% UCL (Student's-t) *	6.091	97.76	6.722	246.2	0.0841	2,299	4,233	30.05	148.5	6.202	147.6	690.4	3.047	0.0717	5.607	190	75.72	2,553	462.4	25.86	1.753	23.44
% of Detects	100	100	100	100	85	100	100	100	96	4	98	100	88	62	100	100	100	100	100	100	0	0
% of Non-Detects	0	0	0	0	15	0	0	0	4	96	2	0	12	38	0	0	0	0	0	0	100	100

* A Non Detect Multiplier of 0.5 has been applied.

Comments

* Converted from objective for Ammonia As N

		BTEX					Physico-chemical	Metals										TRH	PAH		Per- and Polyfluoroall	
		Benzene	Toluene	Ethylbenzene	Xylene Total	Total BTEX	pH	Cadmium	Calcium	Chromium (hexavalent)	Chromium (III+VI)	Chromium (Trivalent)	Copper	Lead	Magnesium	Nickel	Potassium	>C10-C40 Fraction (Sum)	Naphthalene	Sum of PAHs	Perfluorohexane sulfonate	Perfluorooctane sulfonic acid (PFOS)
		µg/L	µg/L	µg/L	µg/L	µg/L	pH_unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL																						
z/s EPL188-03 - Darwin Harbour							6.5-8												90			
z/s EPL188-03 - Darwin Harbour (at 20 deg.C)																						
z/s EPL188-03 - ANZG (2018) Marine water 90%		900						0.0014		0.02	0.02	0.02	0.003	0.0066		0.2						
z/s EPL188-03 - CCME Long Term Marine water																						
z/s EPL188-03 - NEMP 2.0 2020 90% Eco Marine Water																						2
z/s EPL188-03 - ANZECC 2000 Irrigation Long Term Trig								0.01		0.1	0.1	0.1	0.2	2		0.2						
z/s EPL188-03 - ADWG (PCR/Aesthetic)								0.02					20			0.2						
z/s EPL188-03 - ADWG (PCR/Aesthetic)														0.1								
z/s EPL188-03 - NEMP 2.0 2020 Recreational Water																					2	2
z/s EPL188-03 - ADWG Health		1						0.002					2	0.01		0.02						
z/s EPL188-03 - NEMP 2.0 2020 Drinking Water																					0.07	0.07
Location Code	**Date**																					
STG1&2	**06 Feb 2018**	-	-	-	-	-	7.79	<0.0001	111	<0.01	-	<0.01	0.005	<0.001	15	0.005	27	-	-	-	-	-
STG1&2	**06 Mar 2018**	-	-	-	-	<1	7.13	-	-	-	-	-	-	-	-	-	-	<100	<5	<0.5	-	-
STG1&2	**12 Jan 2021**	<1	<1	<1	<3	-	7.6	-	-	-	-	-	-	-	-	-	-	<100	<1	<1	<0.01	<0.01
STG1&2	**10 Feb 2021**	-	-	-	-	-	7.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STG1&2	**14 Apr 2021**	<1	<1	<1	<3	-	6.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STG1&2	**14 Jan 2022**	-	-	-	-	-	5.02	-	23	-	<0.001	-	0.001	<0.001	2.3	<0.001	5.4	-	-	-	<0.01	<0.01
STG1&2	**15 Feb 2022**	-	-	-	-	-	8.33	-	16	-	<0.001	-	0.001	<0.001	2.7	<0.001	7.5	-	-	-	-	-
STG1&2	**08 Apr 2022**	-	-	-	-	-	6.62	-	15	-	<0.001	-	0.001	<0.001	3.5	0.004	8	-	-	-	-	-
STG1&2	**12 May 2022**	-	-	-	-	-	6.49	-	16	-	-	-	-	-	3	-	9	-	-	-	-	-
SW12	**09 Jan 2018**	-	-	-	-	-	6.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**06 Feb 2018**	-	-	-	-	-	7.47	<0.0001	22	<0.01	-	<0.01	0.005	<0.001	9	0.005	15	-	-	-	-	-
SW12	**08 Mar 2018**	-	-	-	-	<1	6.5	-	30	-	-	-	-	-	17	-	15	-	<5	<0.5	-	-
SW12	**10 Apr 2018**	-	-	-	-	-	7.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**14 May 2018**	-	-	-	-	-	8.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**05 Jun 2018**	-	-	-	-	-	7.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**04 Jul 2018**	-	-	-	-	-	7.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**08 Jan 2019**	-	-	-	-	-	10.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**27 Feb 2019**	-	-	-	-	-	8.04	<0.0001	65	<0.01	-	<0.01	0.001	<0.001	36	0.009	72	-	-	-	-	-
SW12	**03 Apr 2019**	-	-	-	-	-	7.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**05 Nov 2019**	-	-	-	-	-	8.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**06 Jan 2020**	-	-	-	-	-	9.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**05 Feb 2020**	-	-	-	-	-	7.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**04 Mar 2020**	-	-	-	-	-	7.88	<0.0001	44	<0.01	-	<0.01	0.021	0.003	15	0.012	61	-	-	-	-	-
SW12	**08 May 2020**	-	-	-	-	-	7.04	-	66	-	-	-	-	-	46	-	41	-	-	-	-	-
SW12	**04 Jun 2020**	-	-	-	-	-	7.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**07 Aug 2020**	-	-	-	-	-	7.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**04 Sep 2020**	-	-	-	-	-	7.36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**12 Oct 2020**	-	-	-	-	-	7.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**04 Nov 2020**	-	-	-	-	-	8.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**03 Dec 2020**	-	-	-	-	-	7.37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**12 Jan 2021**	<1	<1	<1	<3	-	7.28	-	-	-	-	-	-	-	-	-	-	<100	<1	<1	0.03	0.03
SW12	**10 Feb 2021**	-	-	-	-	-	6.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**12 Apr 2021**	-	-	-	-	-	8.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**14 Apr 2021**	<1	<1	<1	<3	-	7.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**10 Jun 2021**	<1	<1	<1	<3	-	7.53	-	84	0.004	-	-	<0.001	<0.001	28	0.01	54	400	<1	<1	-	-
SW12	**09 Jul 2021**	<1	<1	<1	<3	-	10.92	-	39	<0.001	-	-	0.001	<0.001	34	0.002	23	<100	<1	<1	-	-
SW12	**08 Sep 2021**	-	-	-	-	-	8.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**12 Oct 2021**	-	-	-	-	-	7.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**10 Nov 2021**	-	-	-	-	-	6.01	-	34	-	<0.001	-	0.011	0.005	14	0.005	23	-	-	-	-	-
SW12	**08 Dec 2021**	<1	<1	<1	<3	-	7.57	-	55	-	<0.001	-	0.003	<0.001	12	0.002	20	<100	<1	<1	-	-
SW12	**13 Jan 2022**	-	-	-	-	-	6.66	-	28	-	<0.001	-	0.003	<0.001	15	0.002	14	-	-	-	0.01	0.03
SW12	**15 Feb 2022**	-	-	-	-	-	9.03	-	20	-	0.001	-	0.005	<0.001	9.9	0.002	12	-	-	-	-	-
SW12	**10 Mar 2022**	-	-	-	-	-	6.3	-	21	-	-	-	-	-	11	-	11	-	-	-	-	-
SW12	**08 Apr 2022**	-	-	-	-	-	8.25	-	58	-	-	-	-	-	15	-	14	-	-	-	-	-
SW12	**12 May 2022**	-	-	-	-	-	7.63	-	34	-	-	-	-	-	23	-	23	-	-	-	-	-
SW12	**08 Jun 2022**	-	-	-	-	-	6.46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**07 Jul 2022**	-	-	-	-	-	8.36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW12	**11 Aug 2022**	-	-	-	-	-	7.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	BTEX					Physico-chemical	Metals										TRH	PAH		Per- and Polyfluoroall	
	Benzene	Toluene	Ethylbenzene	Xylene Total	Total BTEX	pH	Cadmium	Calcium	Chromium (hexavalent)	Chromium (III+VI)	Chromium (Trivalent)	Copper	Lead	Magnesium	Nickel	Potassium	>C10-C40 Fraction (Sum)	Naphthalene	Sum of PAHs	Perfluorohexane sulfonate	Perfluorooctane sulfonic acid (PFOS)
	µg/L	µg/L	µg/L	µg/L	µg/L	pH_unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Statistics																					
Number of Results	7	7	7	7	2	48	4	19	6	7	4	13	13	19	13	19	6	7	7	4	4
Minimum Detect	ND	ND	ND	ND	ND	5.02	ND	15	0.004	0.001	ND	0.001	0.003	2.3	0.002	5.4	400	ND	ND	0.01	0.03
Maximum Concentration	<1	<1	<1	<3	<1	10.92	<0.0001	111	<0.01	0.001	<0.01	0.021	0.005	46	0.012	72	400	<5	<1	0.03	0.03
Average Concentration *	0.5	0.5	0.5	1.5	0.5	7.6	0.00005	41	0.0041	0.00057	0.005	0.0045	0.001	16	0.0045	24	108	1.1	0.43	0.012	0.018
95% UCL (Student's-t) *	0.5	0.5	0.5	1.5	0.5	7.878	0.00005	51.5	0.00556	0.00071023	0.005	0.00734	0.00172	21.21	0.00637	31.6	225.9	1.788	0.518	0.0265	0.0345
% of Detects	0	0	0	0	0	100	0	100	17	14	0	92	15	100	85	100	17	0	0	50	50
% of Non-Detects	100	100	100	100	100	0	100	0	83	86	100	8	85	0	15	0	83	100	100	50	50

* A Non Detect Multiplier of 0.5 has been applied.

Comments

* Converted from objective for Ammonia As N

	xyl Subst
	Perfluorooctanoic acid (PFOA)
	µg/L
EQL	
z/s EPL188-03 - Darwin Harbour	
z/s EPL188-03 - Darwin Harbour (at 20 deg.C)	
z/s EPL188-03 - ANZG (2018) Marine water 90%	
z/s EPL188-03 - CCME Long Term Marine water	
z/s EPL188-03 - NEMP 2.0 2020 90% Eco Marine Water	632
z/s EPL188-03 - ANZECC 2000 Irrigation Long Term Trig	
z/s EPL188-03 - ADWG (PCR/Aesthetic)	
z/s EPL188-03 - ADWG (PCR/Aesthetic)	
z/s EPL188-03 - NEMP 2.0 2020 Recreational Water	10
z/s EPL188-03 - ADWG Health	
z/s EPL188-03 - NEMP 2.0 2020 Drinking Water	0.56

Location Code	Date	
STG1&2	06 Feb 2018	-
STG1&2	06 Mar 2018	-
STG1&2	12 Jan 2021	<0.01
STG1&2	10 Feb 2021	-
STG1&2	14 Apr 2021	-
STG1&2	14 Jan 2022	<0.01
STG1&2	15 Feb 2022	-
STG1&2	08 Apr 2022	-
STG1&2	12 May 2022	-
SW12	09 Jan 2018	-
SW12	06 Feb 2018	-
SW12	08 Mar 2018	-
SW12	10 Apr 2018	-
SW12	14 May 2018	-
SW12	05 Jun 2018	-
SW12	04 Jul 2018	-
SW12	08 Jan 2019	-
SW12	27 Feb 2019	-
SW12	03 Apr 2019	-
SW12	05 Nov 2019	-
SW12	06 Jan 2020	-
SW12	05 Feb 2020	-
SW12	04 Mar 2020	-
SW12	08 May 2020	-
SW12	04 Jun 2020	-
SW12	07 Aug 2020	-
SW12	04 Sep 2020	-
SW12	12 Oct 2020	-
SW12	04 Nov 2020	-
SW12	03 Dec 2020	-
SW12	12 Jan 2021	0.22
SW12	10 Feb 2021	-
SW12	12 Apr 2021	-
SW12	14 Apr 2021	-
SW12	10 Jun 2021	-
SW12	09 Jul 2021	-
SW12	08 Sep 2021	-
SW12	12 Oct 2021	-
SW12	10 Nov 2021	-
SW12	08 Dec 2021	-
SW12	13 Jan 2022	0.42
SW12	15 Feb 2022	-
SW12	10 Mar 2022	-
SW12	08 Apr 2022	-
SW12	12 May 2022	-
SW12	08 Jun 2022	-
SW12	07 Jul 2022	-
SW12	11 Aug 2022	-

	xyl Subst
	Perfluorooctanoic acid (PFOA)
	µg/L
Statistics	
Number of Results	4
Minimum Detect	0.22
Maximum Concentration	0.42
Average Concentration *	0.16
95% UCL (Student's-t) *	0.397
% of Detects	50
% of Non-Detects	50

* A Non Detect Multiplier of 0.5 has been applied.

Comments

* Converted from objective for Ammonia As N

About Us

WSP is one of the world's leading professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors and environmental specialists, as well as other design, program and construction management professionals. We design lasting solutions in the Transport & Water, Property & Buildings, Earth & Environment, and Mining & Power sector as well as offering strategic Advisory, Engagement & Digital services. With approximately 6,100 talented people in more than 50 offices in Australia and New Zealand, we engineer future ready projects that will help societies grow for lifetimes to come. www.wsp.com/en-au/.

TECHNICAL MEMORANDUM

DATE 30 June 2022 **Reference No.** PS132331-001-M-Rev0

TO Shane Coleman
City of Darwin

CC

FROM WSP Golder **EMAIL**

STAGE 2 INERT LANDFILL SUBSURFACE HOTSPOT, SITE INSPECTION AND INITIAL RECOMMENDATIONS – CITY OF DARWIN, SHOAL BAY WASTE MANAGEMENT FACILITY

1.0 INTRODUCTION AND BACKGROUND

City of Darwin Council (Council) engaged Golder Associates Pty Ltd (WSP Golder) on 10 June 2022 to provide technical support relating to a suspected Hotspot in the Stage 2 Landfill area of the Shoal Bay Waste Management Facility (SBWMF) (the site). We understand there has been evidence of an Active Hotspot observed by site staff since December 2021.

James Begg and Amy MacGregor (both of WSP Golder) attended site over two days to inspect the Stage 2 Landfill area on 22 June 2022 and 23 June 2022. Discussions were held between Council and WSP Golder to discuss air quality monitoring and investigation strategies. This Technical Memorandum provides some initial recommendations to suppress the development of Active and Potential Hotspot(s) and support assessment of current potential air quality impacts a drilling investigation to understand the scale and location of the Active and Potential Hotspot(s).

2.0 STAGE 2 SITE INSPECTION

2.1 Itinerary

Table 1 provides an overview of the site inspections and meetings.

Table 1: Overview of Site Inspections and Meetings

Date	Activity
Day 1 – 22 June 2022	- Meeting at Council Office - Stage 2 site inspection escorted by Veolia - WSP Golder surface walkover and perimeter check - Follow up inspection and discussion with Council
Day 2 – 23 June 2022	- WSP Golder surface walkover - Veolia called to Stage 2 and covered open vent with cover soils - Inspection with Council - Meeting at Council Office

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2.2 Surface Conditions

There are currently various waste streams being organised, and materials being stockpiled on the surface of the Stage 2 Landfill. Large areas of the landform surface were not accessible due to stockpiled materials.

Some photographs taken on Day 1 of the Site Inspection are included in Plate 1 to Plate 4:



Plate 1: Location of recent Hotspot Activity observed by Council (blue marker on Plate 5)



Plate 2 : Tyre stockpiles on the surface of the Stage 2 Landfill



Plate 3 : Mixed waste stockpiles on the surface of Stage 2 Landfill



Plate 4 : Scrap metal sorting on the surface of Stage 2 Landfill

2.3 Evidence of Active Hotspot

On Day 1 there was very strong easterly winds throughout the day. The closest weather station is Darwin Airport, Station 014015, located approximately 5.5 km from the SBWMF which recorded wind speeds of up to 46 km/h on 22 June 2022. . There was an odour of burning tyres observed, on both Day 1 and Day 2, approximately at the location marked by the blue circle on Plate 5. We understand from conversations with Council, that in recent weeks a surface crack formed in this location and smoke began to vent from the crack.

We were shown a video of the crack venting. The cracking was not observed on Day 1 our site inspections. We were informed by both Veolia and Council that area was covered over, using soil stockpiled on the surface of the Stage 2 Landfill area, to reduce air intake.

The subgrade in this location was observed to be uneven and undulating. It is not clear whether this was due to differential settlement caused by Hotspot Activity, normal settlement of waste or due to trafficking and uneven cover soil placement.

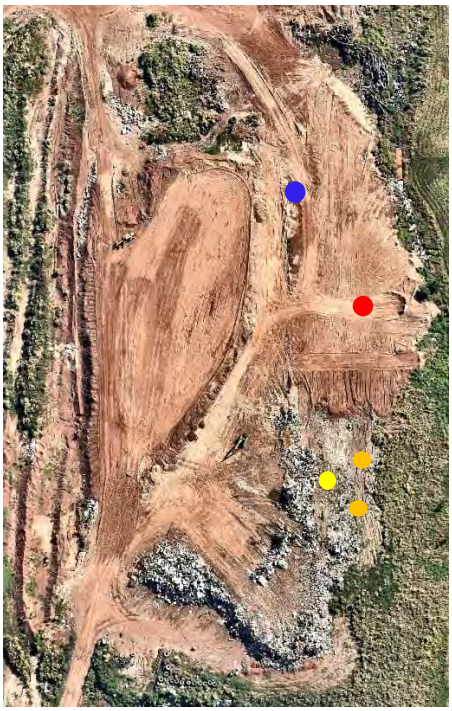


Plate 5 : Hotspot Activity Locations

On Day 2, we observed an area on the surface of the landfill where a sinkhole had formed overnight. We observed smoke venting from surface cracks associated with this area (Plate 6). The approximate location is shown by the red circle on Plate 5. This area was immediately covered by Veolia with approximately 300 mm of soil cover.



Plate 6 : Hotspot venting observed on Day 2 of Site Inspection

Also on Day 2, we observed two other active vents during a walkover of the Stage 2 Landfill area which were observed to be circular shaped holes in the waste surface, there was smoke arising from the vents and staining of the soil/waste on the surface. The approximate locations are shown as orange circles on Plate 5. An additional location which is suspected to be an inactive vent (characteristic staining was observed with no smoke arising from the opening), was found during the walkover. This location has been marked on the plan above as the yellow circle, as it is an area which should be monitored for change. Although, in the absence of smoke (active signs) we cannot confirm that it is a location of Hotspot Activity from surface observations.

3.0 POTENTIAL SOURCE OF HOTSPOT

3.1 Landfilled Materials

Over the lifetime of the Stage 2 Landfill there has been various materials buried throughout. It is understood that large shipping containers containing Asbestos Containing Materials (ACM) and bundles of tyres have been used to delineate the active waste filling areas and therefore have been buried in rows. Visual observations and anecdotal information from Council and Veolia also indicate that ACM is likely to be present throughout buried inert materials within Stage 2.

Using aerial photographs, the locations of these shipping containers and tyre stockpiles has been approximately mapped and presented on Plate 7. The blue rectangles on Figure 6 represent shipping container locations, and the red areas represent areas of buried tyres. The mapping of waste types is limited to what was observed on the aerial photographs reviewed. We have presented the approximate location of shipping containers and tyre bundles which appear in the aerial footage, though we note there could be areas where these materials were placed and buried between available aerial photographs. The aerial photographs we inspected are generally 12 months apart.

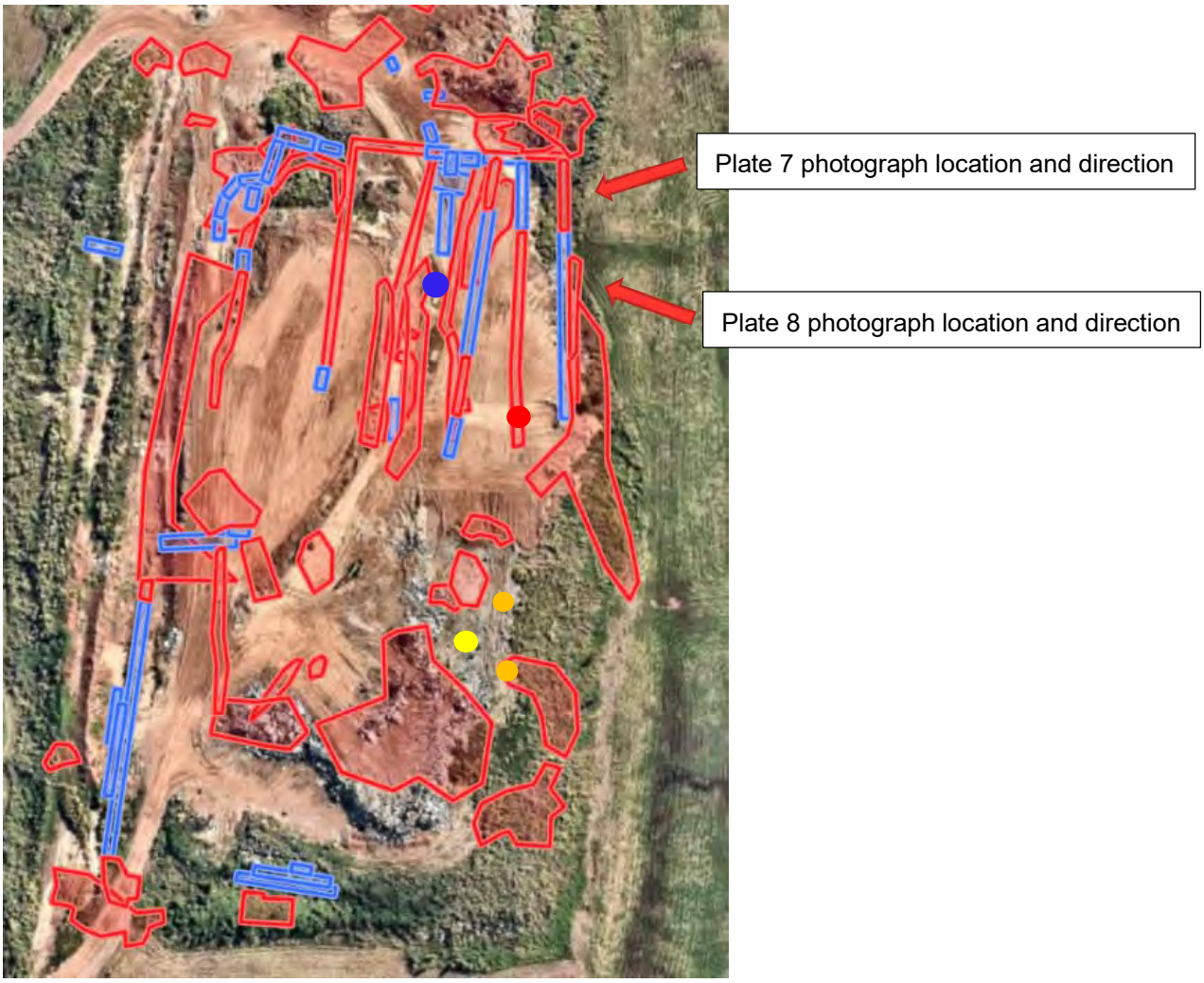


Plate 7 : Areas of buried shipping containers (blue rectangles) and tyres (red polygons)

3.2 Suspected Air Source

It is understood from aerial photos and conversations with Council, that waste filling in Stage 2 was undertaken in a manner where windrows (of approximately 100 m length, at a typical spacing of roughly 25 m) were formed comprising tyres and/or shipping containers containing ACM. These windrows were used to delineate the daily operational area and waste was placed between these windrows and covered with cover soils. Based on our review of aerial photographs of Stage 2, it appears that cover soils were pushed out from above and only pushed out as far as the barricade of tyres and/or shipping containers – not over the edge to cover the open face of the windrow of waste.

When viewing the landform from the perimeter, particularly on the eastern side of Stage 2, there is an uncompacted, exposed waste face which represents a potential pathway for air intake directly to the waste mass. This can be seen in the photographs presented as Plate 8 and Plate 9.



Plate 8 : Eastern batter of exposed waste (northern section)



Plate 9 : Eastern batter of exposed waste (southern section)

4.0 INITIAL RECOMMENDATIONS

4.1 Exclusion Zone

We recommend the existing exclusion zone be increased to include the entire eastern portion of Stage 2, as outlined in Plate 10 (refer red shaded area). This exclusion zone should restrict direct access by personnel. We recommend that light vehicle and heavy plant be further restricted to prevent access with the aim to avoid potential sinkholes in the waste. Trafficking should be minimised until interim cover works have occurred and

subject to further consideration of site risks by the Project Team, preferably including further discussion with WSP Golder prior to all forms of access to the restricted area. If access is necessary, a Safe Work Method Statement (SWMS) including a detailed risk assessment should be completed and be approved by both the Veolia Project Manager and Council.



Plate 10 : Stage 2 recommended Exclusion Zone

It was observed onsite that an area had been marked out by traffic cones to reduce access to the area which developed a venting crack (blue marker on Plate 5). We recommend delineating the full exclusion zone clearly onsite by use of closely spaced markers, bunting or similar. The exclusion area should be notified to all site Contractors and we recommend use of signage to avoid unexpected trafficking by persons onsite, such as third party workers coming onsite for maintenance activities.

4.2 Decommission Gas Infrastructure

LMS Energy confirmed via email on 28 June 2022 there is existing gas infrastructure within Stage 2 which we understand to be actively extracting landfill gas. The layout of active infrastructure is presented in Plate 11.

We recommend that all landfill gas infrastructure within Stage 2 be temporarily decommissioned and/or diverted. Due to the unknown extents of the Potential and Actual Hotspot(s) within Stage 2, allowing landfill gas infrastructure within the landfill to remain operational is considered to be an avoidable risk which should be mitigated.

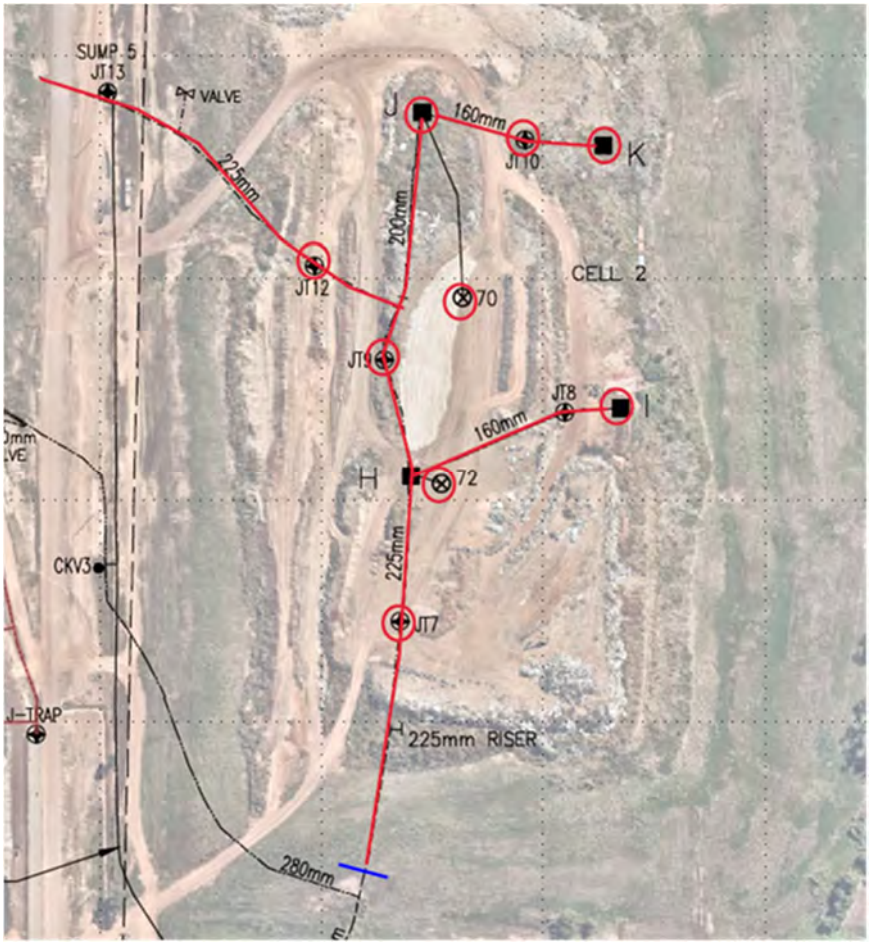


Plate 11 : Gas Infrastructure as provided by LMS Energy on 28 June 2022

4.3 Remove Surface Waste Stockpiles

To enable cover soils to be placed evenly and ultimately to permit the drilling investigation to be carried out, we recommend that all surface stockpiles of waste be removed or relocated from the eastern portion of Stage 2. The area we recommend clearing (as a minimum) matches the recommended exclusion zone boundary presented on Plate 10. Due to this area being inside the recommended exclusion zone, clearing activities will require an approved SWMS.

4.4 Interim Cover Soils

We understand the challenges associated with obtaining clay rich soils in Darwin and believe the urgency of reducing air intake to be of highest initial priority. Therefore, we recommend that a cover soil layer be constructed using soils available and stockpiled at the site.

To achieve the best interim cover layer in regard to reducing air intake, we recommend that the soil cover is placed as follows:

- Soil shall be placed in layers of approximately 300 mm thickness,
- A minimum of two 300 mm layers shall be placed,
- Soil shall be moisture conditioned both at the stockpile location and once in place,
- Compaction shall be achieved by trafficking with the onsite compactor.

We understand there is a compactor on site which may be utilised in the earthworks. However, in the absence of a compactor, wheel/track rolling shall be used to provide a firm interim cover/capping layer. We propose that during cover placement, benches be constructed into the final surface to support drill rig access to complete the hotspot investigation works.

WSP Golder will prepare a Benching Layout Plan for Council to provide to Veolia, whom we understand will undertake the proposed earthworks.

4.5 Develop a Hotspot Remediation Action Plan

We recommend that a Hotspot Remediation Action Plan be developed and updated as the works progress to provide a primary document for all staff working in Stage 2, which contains the following:

- Roles and responsibilities.
- Essential contact details.
- Proposed investigation/remediation strategies.
- Air quality monitoring plan.
- General hotspot risk assessment and response/procedures.
- A document register including other relevant plans or documents prepared during the works and SWMS for individual activities and their review/approval.

We recommend that Council begin to file all documentation related to Hotspot Remediation in one location as it is likely that the NTEPA will request documentation at various stages of the works.

4.6 Initial Air Quality Monitoring

The NTEPA has requested that Council perform initial air quality monitoring to assess whether the current state of the Hotspot is impacting the residents in the surrounding area. WSP Golder has been commissioned to undertake this air quality monitoring. An initial air quality monitoring program has been prepared based upon site observations, prevailing wind conditions and proximity to potential receptors. The scope of the initial monitoring program is proposed to be presented to Council and the NTEPA for discussion in parallel with sourcing and mobilising specialised equipment, experienced field staff and security.

4.7 Drilling Investigation

The soil cover is important not only to reduce air intake but also to permit a drill rig to safely traffic the Stage 2 Landfill area.

We recommend that once a drill rig becomes available and the surface conditions are improved to support suitable equipment access that a drilling investigation be commenced. A drilling investigation will be

undertaken to provide information regarding the depth and footprint of Hotspot(s). This investigation will inform the Remediation Options Assessment, and later versions of the Hotspot Remediation Action Plan.

4.8 Hotspot Suppression Works

The widespread presence of ACM throughout buried waste within Stage 2 represents a high potential risk to human health from any disturbances. Given the potentially large extent of hot spots it is recommended that Council does not commence works to expose and suppress known hot spots until site conditions are better understood, the Hotspot Remediation Action Plan is prepared, and suitable controls are put in place.

5.0 NTEPA AUTHORISED OFFICE DIRECTION PROGRAM

The NTEPA Authorised Office Direction Notice sets task completion dates summarised in Table 2.

Table 2: NTEPA Direction Notice Deadline and Status Summary

Date	Direction	Current Status
Immediate	Prevent environmental harm	■ Initial covering of known hot spots completed ■ Initial exclusion zone established ■ Covering of hot spots identified by WSP Golder underway ■ Council/Veolia establishing expanded exclusion zone ■ Council/Veolia commenced larger scale interim capping works to reduce air intake opportunities ■ Timeframes for completion of expanded interim capping works to be confirmed by Council.
15 June 2022	Engage Suitably Qualified Environmental Consultant	■ WSP Golder engaged on 10 June 2022
1 July 2022	Location and extent of hot spots	■ Current known extent based on visual observations only. ■ Subsurface investigations required to assess full extent and current status. ■ Initial investigation and monitoring works unlikely to be completed until end of August at the earliest.
	Identify exclusion zones	■ Current known extent based on visual observations only. ■ Council/Veolia to expand exclusion zone based on known information by 1 July 2022.
15 August 2022	Hot Spot Suppression Strategy	■ Requires completion of initial hop spot investigations (end of August) ■ Requires review of hot spot suppression strategies (August/September). Due to presence of ACM may require use of alternative solutions. ■ Earliest implementation is likely to be end of September.
30 August 2022	Development and implementation of Monitoring Program	■ Initial air quality monitoring targeted for completion by 30 August 2022.

Date	Direction	Current Status
		■ Initial hot spot investigations targeted for completion by 30 August 2022. ■ Longer term air quality and hot spot monitoring programs to be developed in conjunction with Hot Spot Suppression Strategy.

6.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled – "Important Information Relating to this Report", which is included in Attachment A of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations WSP Golder has under the contract between it and its client.

7.0 CLOSING

We trust the information presented in this Technical Memorandum meets the expectations of Council. Please contact the undersigned if you would like to discuss further.

We understand that there is a meeting scheduled on 21 July 2022 with Council and the Northern Territory Environmental Protection Authority. Council has requested WSP Golder's presence at that meeting to discuss the content of this Technical Memorandum.

Golder Associates Pty Ltd

Amy MacGregor
Civil Engineer

James Begg
Principal Engineer

AGM/ATG/agm

Distribution:

Attachments: Attachment A - Important Information Relating to this Report

https://golderassociates.sharepoint.com/sites/162689/project files/6 deliverables/ps132331-001-m-rev0 site inspection and initial recommendations.docx

ATTACHMENT A

Important Information Relating to this Report

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

DRAFT

REPORT

(DRAFT) Interim Stage 2 Inert Landfill Subsurface Hotspot Remediation Action Plan August 2022 Revision

Shoal Bay Waste Management Facility, Darwin

Submitted to:

City of Darwin

Submitted by:

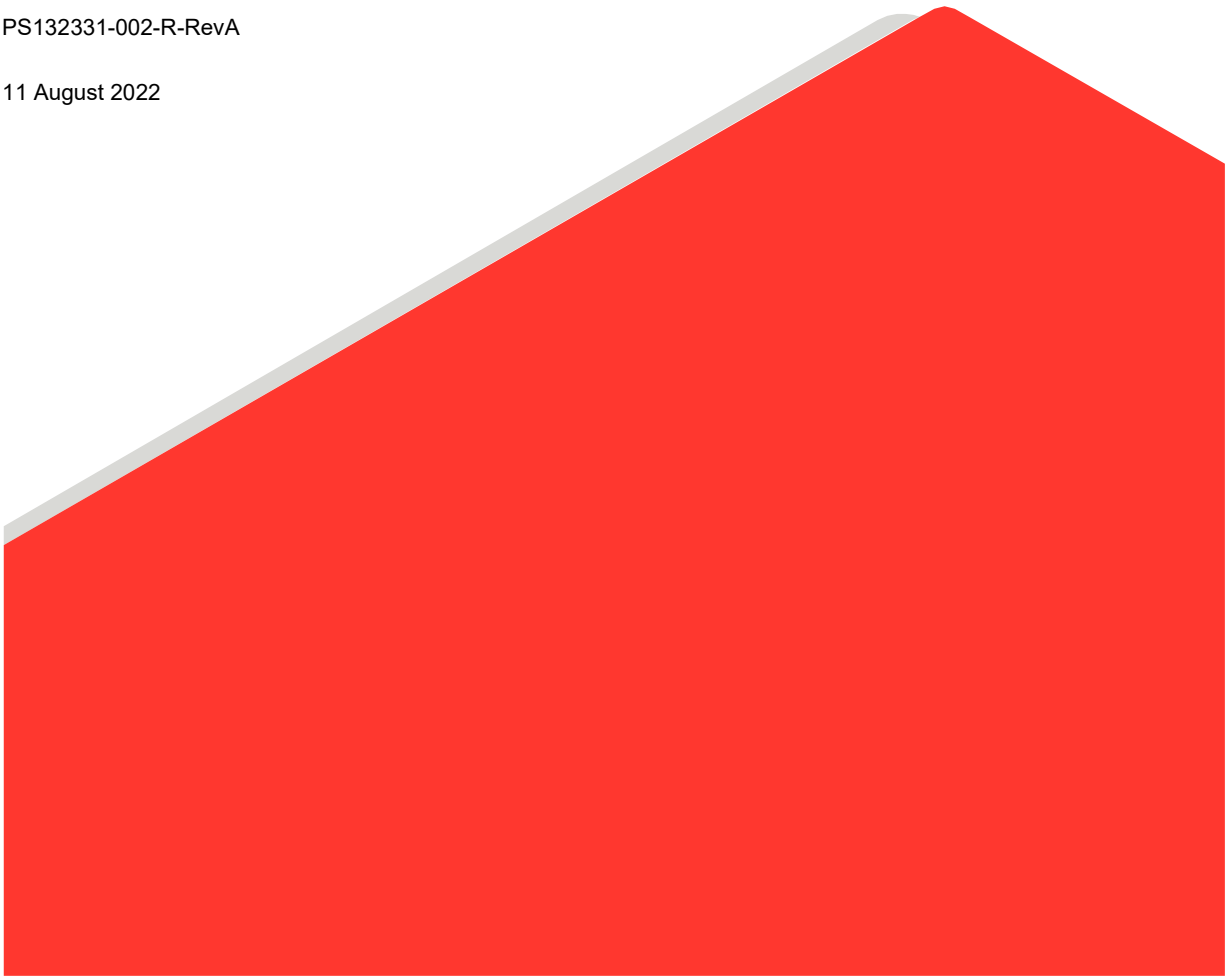
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PS132331-002-R-RevA

11 August 2022



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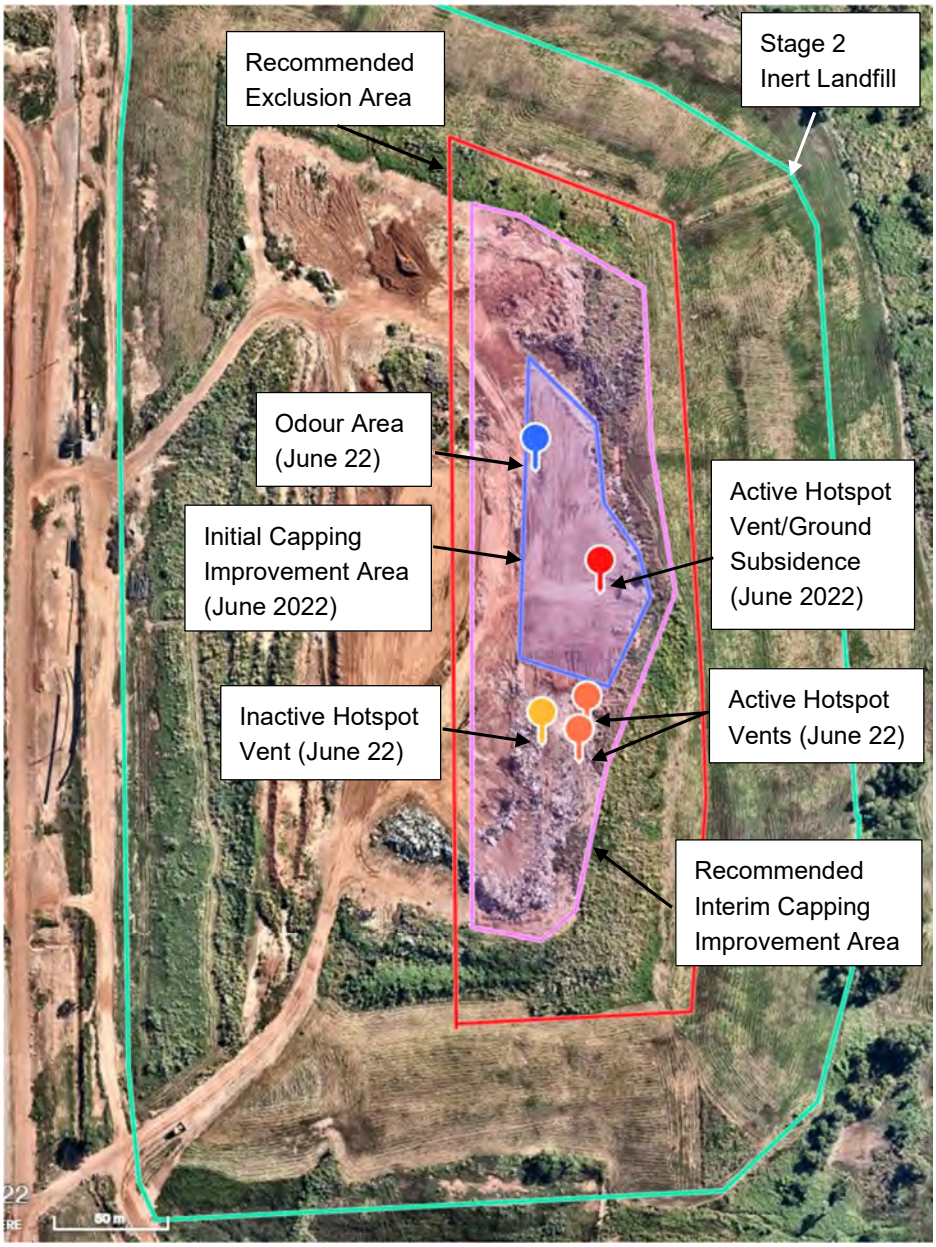
Company	Client Contact	Version	Date Issued	Method of Delivery
City of Darwin	Shane Coleman	Revision A (Draft)	11 August 2022	Email

Executive Summary

The Northern Territory Environment Protection Authority issued the City of Darwin with an Authorised Officer Direction Notice on 19 May 2022 requiring the assessment and mitigation of active subsurface hotspot conditions observed with the Stage 2 Inert Landfill at the Shoal Bay Waste Management Facility (SBWMF). WSP Australia Pty Ltd has been engaged by Council to provide technical support to Council.

This Interim Subsurface Hot Spot Remediation Action Plan presents proposed methodologies to investigate, assess, manage and ultimately mitigate identified hotspot conditions and associated risks to human health and the environment. This is a live document that will be updated regularly as the subsurface hotspot conditions are better understood and management and mitigation strategies are selected, implemented and adjusted to suit observed conditions.

Summary of Known Hotspot Conditions and Interim Controls – August 2022



Current Project Status Summary - Assessments

Project Element	Purpose	Responsible	Status	Start Date	End Date
Initial Site Inspection	■ Understand known hotspot conditions ■ Understand waste placement material types and methodologies	Council WSP Golder	Completed	Jun 2022	Jun 2022
Aerial photography review and development of 3D waste placement model	■ Support investigation locations ■ Understand hotspot migration pathways ■ Support assessment of hot spot mitigation strategies	WSP Golder	Nearly completed	Jun 2022	Aug 2022
Desktop literature review	■ Identify potential contaminants of concern associated with landfill hot spots	WSP Golder	Commenced	Aug 2022	Aug 2022
Preparation of conceptual site model	■ Identify potential human health and environmental receptors and potential hazard exposure pathways ■ Understand potential migration pathways	WSP Golder	Commenced	Aug 2022	Aug 2022
Air quality investigation	■ Identify potential existing air quality impacts within and adjacent to the SBWMF ■ Support human health and environmental risk assessments	WSP Golder	Planned	Aug 2022	Sep 2022
Surface Water and Groundwater monitoring data review	■ Identify potential changes to water quality that could potentially be associated with hotspot conditions	WSP Golder	Planned	Aug 2022	Sep 2022
Initial hotspot drilling investigations	■ Identify the approximate horizontal and vertical extent of hot spot conditions within the landfill ■ Support the selection of preferred hotspot management/mitigation strategies	WSP Golder Veolia	Driller booked	Aug 2022	Sep 2022
Initial human health and environmental risk assessments	■ Identify potential impacts to air quality and water quality from existing hotspot conditions that may represent a potential risk to human health and the environment ■ Identify potential impacts to air quality and water quality from potential hotspot management and mitigation	WSP Golder	Pending other assessments	Sep 2022	Nov 2022

Project Element	Purpose	Responsible	Status	Start Date	End Date
	strategies that may represent a potential risk to human health and the environment				
Hotspot management/mitigation works human health and water quality monitoring programs	■ Identify potential impacts to air quality and water quality from the implementation of hotspot management and mitigation program	To be confirmed	Pending strategy selection	To be confirmed	To be confirmed
	■				

Current Project Status Summary – Rehabilitation Works

Project Element	Purpose	Responsible	Status	Start Date	End Date
Interim capping of exposed waste	■ Reduce oxygen inflow into waste mass	Council Veolia	Nearly completed	Jul 2022	Aug 2022
Review of potential practical hotspot mitigation strategies	■ Identification and selection of preferred hotspot management and mitigation solutions	WSP Golder	Commenced	Jul 2022	Nov 2022
Implementation of preferred hotspot management/mitigation strategy	■ Management and mitigation of hotspot conditions	Council Veolia	Pending strategy selection	To be confirmed	To be confirmed
	■				

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APPENDICES

APPENDIX A
IMportant Information

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Type Appendix title here.

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Important Information

1.0 INTRODUCTION

1.1 Background

City of Darwin Council (Council) engaged WSP Australia Pty Ltd (WSP Golder) on 10 June 2022 to provide technical support relating to subsurface hotspot conditions with the Stage 2 Inert Landfill area at the Shoal Bay Waste Management Facility (SBWMF). It was understood that a hotspot was first observed by site staff in late December 2021, with attempts to smother the hotspot conditions and additional hotspots observed up to March 2022.

Council notified the Northern Territory Environment Protection Authority (NTEPA) of the initial hotspot conditions on 27 December 2021. On 19 May 2022, Council received an Authorised Officer Direction from NTEPA, presented in Appendix A, that required Council to:

- Preventing waste disposal and access to areas within Stage 2 with evidence of hotspot conditions.
- Engage a suitably qualified environmental consultant by 15 June 2022 to:
  - a) By 1 July 2022 identify the extent of hot spot conditions and confirm exclusion area
  - b) By 15 August 2022 develop a strategy to extinguish hot spot conditions
  - c) By 30 August 2022 develop and implement monitoring programs to assess potential contaminants of concern and associated risks to human health and the environment.

This Interim Subsurface Hot Spot Remediation Action Plan presents the proposed methodologies to investigate, assess, manage and ultimately mitigate identified hotspot conditions. This is a live document that will be updated regularly as hotspot conditions are better understood and management and mitigation strategies are assessed, selected, implemented and adjusted to suit observed conditions.

1.2 Key Project Organisations and Contacts

Key parties and contacts to the assessment, management and mitigation of the Stage 2 Inert Landfill subsurface hotspot conditions are presented in Table 1.

Table 1: Key Project Contacts

Key Personnel	Email	Phone
City of Darwin – Owner of SBWMF Operations		
Mr Nick Fewster	nick.fewster@darwin.nt.gov.au	
Mr Shane Coleman	shane.coleman@darwin.nt.gov.au	0428 912 694
Department of Defence – Landowner		
To be confirmed		
Northern Territory Environment Protection Agency – Site Operations Regulator		
Veolia Environmental Services Pty Ltd (Veolia) – Landfill Operations Contractor		
Mr Nick Walker	nick.walker@veolia.com	
Mr Mick Atkin	mick.atkin@veolia.com	

Key Personnel	Email	Phone
WSP Golder – Hotspot Technical Support		
Mr Bruce Dawson		
Mr Andrew Green		
Mr James Begg		
Ms Amy Macgregor		

1.3 Document List

Prepared documents relevant to the investigation, assessment, management and mitigation of the Stage 2 Inert Landfill subsurface hotspot conditions are listed in Table 2.

Table 2: Relevant Document List

Organisation	Document	Reference	Date	Appendix
NTEPA	Authorised Officer Direction Notice	EN2011/0028-04-0216	19 May 2022	A
WSP Golder	Subsurface Hotspot Site Inspection and Initial Recommendations	PS132331-001-M-Rev0	30 Jun 2022	B

2.0 MONITORING, INVESTIGATION AND ASSESSMENT PROGRAM

2.1 Council/Veolia Monitoring

Standard landfill operation and management plans for the SBWMF include the following routine inspections and monitoring programs:

- Veolia undertake a daily inspection within the SBWMF that includes identification of visible subsurface hotspot conditions such as smoke and ground subsidence of active waste disposal areas.
- Council and Veolia undertake weekly inspections within the SBWMF that includes that includes identification of visible subsurface hotspot conditions such as smoke and ground subsidence across active, dormant and closed waste disposal areas.

It is understood that since the identification of subsurface hot spot conditions within the Stage 2 Inert Landfill in late December 2021, the routine inspection and monitoring programs have been adjusted to include daily inspection of the known hotspot and adjacent areas.

2.2 Initial WSP Golder Site Inspection

An initial site inspection of the known hotspot areas and conditions was undertaken by WSP Golder on 22 and 23 June 2022 as documented in Appendix B. Inspections undertaken on the first day did not provide visible indications of hot spot conditions such as smoke or ground subsidence, however, a burning odour was evident near the location of a hotspot previously observed by Council/Veolia in March 2022.

Inspections on the second morning observed ground subsidence and venting smoke within the hotspot area originally identified by Council/Veolia in December 2021. Further inspection identified active and inactive hotspot vents to the south of previously observed hotspot areas.

The site inspection noted the presence of uncovered waste material along the eastern batter of the Stage 2 Inert Landfill that may provide an active pathway for air migration into active hotspot areas.

2.3 Aerial Photography Review/3D Waste Model

A preliminary review of aerial photography of the Stage 2 Inert Landfill from 2012 onwards identified the ongoing burial of a series of shipping containers and bundles of tyres that may represent preferential hotspot fuel sources, migration pathways and potential confinement barriers as shown on Figure 1.

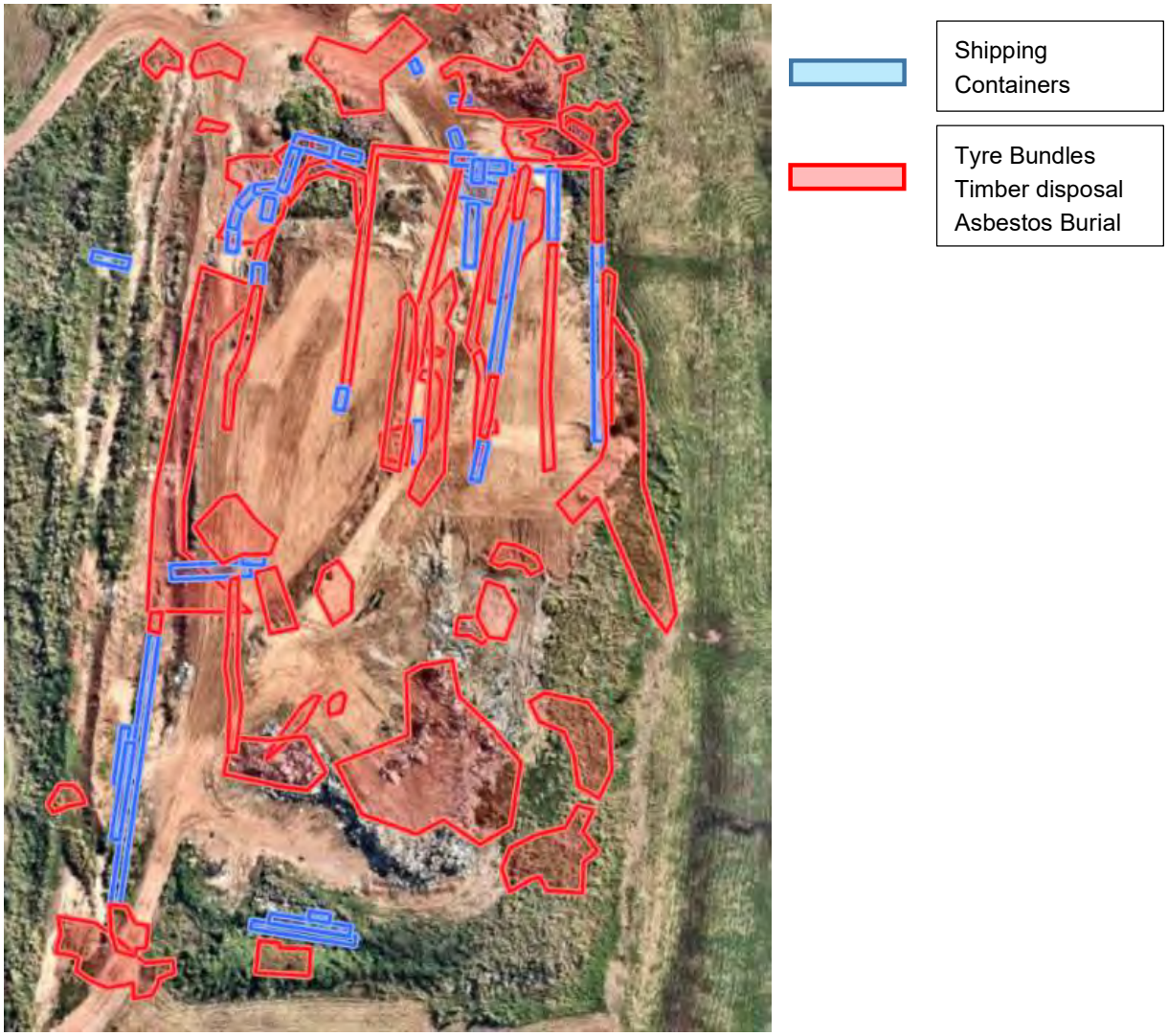


Figure 1 : Preliminary Identified Container, Tyre and Asbestos Burial Areas 2012 to 2022

WSP Golder is currently undertaking a more detailed review of available aerial photography and waste survey data to prepare a 3D model of shipping containers, tyre bundles and known timber and asbestos burial areas to assist with:

- Identification of potential impediments to subsurface investigations
- Targeting subsurface investigations at potential hotspot fuel sources (i.e. tyre and timber bundles)
- Understanding potential hotspot migration pathways and confinement barriers

2.4 Subsurface Hotspot Extent

WSP Golder is planning to undertake a subsurface investigation program to assist with identification of the extent and depth of hotspot conditions within the Stage 2 Inert Landfill. The investigation methodology comprises drilling small diameter investigation boreholes into the waste using a truck mounted rotary drill rig to install galvanised steel standpipes that will be grouted around the exterior and capped to allow ongoing access and monitoring. Temperature and gas concentration measurements will be measured as each borehole is advanced. The installed steel standpipes will be used to support monitoring temperature across the depth of the landfill waste column and potential changes to temperature conditions over time.

Initial drilling locations will be chosen based on known hot spot conditions, the location of potential impediments (i.e. shipping containers) and potential fuel sources. Subsequent drilling locations will be based on observations from the initial drilling locations and attempting to identify the extent of hot spot conditions.

Securing a drilling company to mobilise to site to undertake the investigation works has been difficult to date. Discussions with a contractor who may be able to commence works in late August or early September 2022 are current being undertaken.

The number and depth of monitoring locations will be reviewed as the investigation program progresses.

2.5 Risks to Human Health and Environment

2.5.1 Desktop Literature Review

A desktop literature review is being undertaken by WSP Golder to identify key potential contaminants of concern that may be generated by the landfill hotspot conditions and potentially impact human health and environmental receptors, both on-site and in surrounding areas. It is anticipated that the primary potential contaminant migration pathways would comprise air, surface water and groundwater.

2.5.2 Conceptual Site Model

Following completion of the desktop literature review preparation of a Conceptual Site Model would be commenced to identify potential contaminant sources, potential human health and environmental receptors and potential migration pathways.

The Conceptual Site Model will be regularly reviewed and updated based on the findings of site investigation and monitoring programs. The Conceptual Site Model will form the basis of assessing risk to human health and the environment from the subsurface hotspot conditions.

2.5.3 Air Quality Monitoring

TBC

2.5.4 Existing Water Quality Monitoring Data Review

TBC

2.5.5 Qualitative Risk Assessments

TBC

2.6 Rehabilitation Air and Water Quality Monitoring

An air and water quality monitoring program would be developed to support the preferred hotspot rehabilitation strategy prior to implementation based on identified on-site and off-site human health and environmental receptors of concern and potential contaminant migration pathways.

3.0 MANAGEMENT AND MITIGATION PROGRAM

3.1 Council/Veolia Directed Works to Date

It is understood that Council/Veolia have undertaken the following hotspot mitigation works to date:

- December 2021
  - Placement of improved capping across and surrounding the identified hotspot location
- March 2022
  - Interim placement of improved capping across and surrounding the identified hotspot location
  - Excavation of identified hotspot area, with smothering of disturbed material
  - Excavation depth (approximately 6 m) and extent ceased based upon visual observations
  - Excavation flooded with water in attempt to smother potential unknown adjacent hotspots
  - Excavation backfilled with smothered waste material and capped with clean soil.

3.2 Initial WSP Golder Recommendations

Based upon the site inspection undertaken on 22/23 June 2022, WSP Golder provided the following recommendations as documented in Appendix B:

- Expansion of the waste disposal, personnel and equipment exclusion zone.
- Disconnection of all landfill gas collection infrastructure within the Stage 2 Inert Landfill.
- Removal of all exposed surface waste stockpiles from the exclusion area.
- Placement of interim cover soils across all exposed wastes located within the exclusion area, particularly focusing on the containers, tyre bundles, concrete rubble and other material located along the eastern extent that may provide an air inflow pathway.

3.3 Preliminary Options Review

3.3.1 General

WSP Golder have reviewed potentially options to manage and mitigate the known hotspot conditions with the Stage 2 Inert Landfill. This review will be updated based upon the findings of the proposed site investigations to identify the extent and depth of hotspot conditions present.

3.3.2 Key Hazards

Smothering of Hot/Smouldering/Burning Waste

The globally industry standard to achieve complete extinguishment of hotspots is to excavate, smother and then rebury waste material after it has cooled sufficiently. Key elements of this process may include:

- Excavation and handling of hot/smouldering waste that may spontaneously combust when exposed to air.
- Where open flames occur, immediate placement of excavated waste within hardstand areas to smother reduce temperatures using water or soil.
- Short term placement of excavated waste within a hardstand and spraying with water to fully cool and extinguish smouldering waste with water, including at least one turnover and additional water spraying event.

- Drying of the excavated waste prior to reburial.

Use of water to cool/extinguish waste may require use of containment infrastructure to prevent release of contaminants to the environment.

Use of soil to assist with smothering/cooling excavated waste may increase the volume of material that requires reburial. The scale and speed of excavation waste excavation and smothering works will also be dependent on the size of hardstand areas available, the volume of water available and the capacity available to rebury waste whist hotspot excavation works continue.

Asbestos Containing Material

The Stage 2 Inert Landfill has been used to disposal of large volumes of asbestos containing material (ACM) in the form of:

- Multiple shipping containers containing ACM
- Plastic-wrapped bundles (small to truck size)
- Within inadvertent mixed loads of construction and demolition waste

Excavation of buried waste material within the Stage 2 Inert Landfill is likely to disturb and expose ACM that would require careful management and controls to mitigate potential exposure risks to the health of site personnel.

Tyres and Timber Bundles

The Stage 2 Inert Landfill has been used to disposal of large volumes of vehicle tyres and trees in the form of:

- Large size, compacted tyre bundles
- Large size loose tyre bundles
- Individual tyres
- Large size loose bundles of tree trucks, branches and root balls.

Continuous rows of buried tyre bundles are known to be located within identified subsurface hotspot areas.

It is likely that excavation of buried waste within the known hotspot areas will disturb and expose potentially hot and smouldering tyres and tree parts that may:

- Spontaneously ignite when exposed to air.
- Impact air quality
- Result in noticeable odour issues both on-site and off-site.

Landfill Containment Infrastructure

The Stage 2 Inert Landfill is located within the footprint of the original Stage 2 General Waste Landfill that ceased operation in approximately 2002. It is understood that both the inert and general waste landfills were constructed and operated without installed engineered leachate containment liners and collection systems.

The known hotspot conditions, therefore, represent a low risk of damage to existing landfill leachate containment and collection infrastructure that could result in the uncontrolled release of leachate that could impact surface water and groundwater quality.

3.3.3 Option 1 – Waste Excavation and Smothering

Option 1 comprises the complete excavation of buried waste hotspots to enable hot/smouldering material to be cooled and smothered using methods such as soil, cover, water application or mechanical breakdown.

As noted above, this option is generally considered the most reliable methodology to achieve full extinguishment of large scale and deep landfill hotspots, however, needs to be considered in the context of potential disadvantages as summarised in Table 3.

Table 3: Option 1 - Excavation and Smothering

Key Advantages	Key Disadvantages
■ Proven methodology to abate large, deep waste hotspot conditions	■ Likely to disturb and expose ACM that requires controls to protect human health during the handling process. ■ Likely to disturb and expose smouldering tyres and timber that may spontaneously combust. both within disturbed and undisturbed materials. ■ Introduction of air from excavations into undisturbed waste may cause the spread of adjacent hotspot conditions at a rate faster than the excavation works. ■ Likely to disturb and expose smouldering tyres and timber that may result in significant odour impacts on-site and off-site. ■ Largescale excavations may take considerable time and require large hardstand areas and potential alternative waste reburial cells. ■ Run-off from water cooling hardstands required to be contained and managed as leachate. ■ Large scale excavations will incur significant costs.

3.3.4 Option 2 – Water Flooding

Option 2 comprises injection and/or flooding of in-situ hotspot conditions within the landfill. It primarily relies on water entering voids within the waste material to cool and extinguish individual smouldering materials.

This method has been used at the SBWMF previously, however, it may not be effective for large, hotspot conditions and represents significant risks of uncontrolled steam releases and could be responsible for spreading hotspot conditions within the waste mass as summarised in Table 4.

Table 4: Option 2 – Water Flooding

Key Advantages	Key Disadvantages
■ Potentially limits the disturbance of buried waste material and impacts associated with: ▪ ACM management ▪ Spontaneous combustion ▪ Significant odours	■ Injection of water into waste hotspots above 100°C may result in uncontained release of steam that represents a significant risk of death or injury. ■ Injection of water into waste hotspots above 100°C may result in uncontained release of steam and heat into adjacent waste areas that may spread hotspot conditions. ■ There is no existing leachate containment and collection infrastructure to control the release of potentially contaminated water being released into the environment. ■ The limited water capacity available at the SBWMF may not be sufficient to materially change large and deep hot-spot conditions. ■ Uncertain whether water flooding will fully abate hotspot conditions.

3.3.5 Option 3 – Gas Flooding

Option 3 comprises the injection of non-combustible gases such as carbon dioxide or nitrogen into the waste mass to exclude oxygen and smother hot-spot conditions. Key advantages and disadvantages of this option are summarised in Table 5

Table 5: Option 3 – Gas Flooding

Key Advantages	Key Disadvantages
■ Potentially limits the disturbance of buried waste material and impacts associated with: ▪ ACM management ▪ Spontaneous combustion ▪ Significant odours ■ Use of liquid gasses will assist with cooling waste within hotspot areas.	■ Use of carbon dioxide will result in direct release of greenhouses to the atmosphere. ■ The volume of gas required to abate large and deep hotspot condition may be beyond the available supply capacity. ■ Gas flooding may not fully abate hotspot conditions. ■ Large scale use of gas will incur significant costs.

3.3.6 Option 4 – Firefighting Foam

Option 4 comprises the injection of firefighting foam into the waste mass to exclude oxygen, smother hot-spot conditions and provide a non-flammable coating that restricts further spreading. Desktop research by fire engineers has indicated that the use of firefighting foams could potentially be suitable to control and mitigate hotspot conditions in landfills based upon their experience with similar subsurface fire conditions at coal mine and other facilities. We note however, that there are no known cases of firefighting foams being used within large scale and deep landfill hotspots.

Use of this option is likely to require multiple trials to assess its potential effectiveness prior to being implemented at large scale. Key advantages and disadvantages of this option are summarised in Table 6.

Table 6: Option 3 – Firefighting Foam

Key Advantages	Key Disadvantages
■ Potentially limits the disturbance of buried waste material and impacts associated with: ■ ACM management ■ Spontaneous combustion ■ Significant odours ■ Use of firefighting foam will assist with cooling waste within hotspot areas.	■ No known large-scale implementation. ■ Requires foam to penetrate most waste voids to provide adequate coating and protection. ■ Multiple small-scale trials will be required to assess performance prior to implementation. ■ Firefighting foam may not fully abate hotspot conditions. ■ Large scale use of firefighting foam will incur significant costs.

3.3.7 Option 5 – Combination of Control and Mitigation Measures

Option 5 comprises the adoption of a combination of potential control options to adequately to contain and mitigate hotspot conditions to protect human health and the environment.

The selection of appropriate controls and mitigation options would be based upon the findings of the planned hotspot investigation program and human health and environmental risk assessments.

Key advantages and disadvantages of this option are summarised in Table 7.

Table 7: Option 3 – Firefighting Foam

Key Advantages	Key Disadvantages
■ Potentially limits the disturbance of buried waste material and impacts associated with: ■ ACM management ■ Spontaneous combustion ■ Significant odours ■ Potentially achieves appropriate human health and environmental protection outcomes using options that are practical, feasible and cost effective.	■ May require extended implementation timeframe. ■ May require use of ongoing exclusion zones that may limit ongoing use for waste disposal and restrict planned expansion works. ■ May not fully abate hotspot conditions.

3.4 Proposed Rehabilitation Strategy

The rehabilitation strategy to manage and mitigate the Stage 2 Inert Landfill hotspot conditions will be developed based upon the findings of proposed investigations and assessments and in consultation with Council and the NTEPA.

4.0 PRELIMINARY EMERGENCY RESPONSE PLAN

Known hotspot conditions within the Stage 2 Inter Landfill represent a potential risk to human health and the environment, including smoke release, ground subsidence and surface fires.

Potential site conditions and proposed emergency responses are sumarised in Table 8.

Table 8: Emergency Response Plans

Event	Emergency Response
■ Open vents emitting visible smoke	■ If required, expand existing exclusion zone to include identified hot spot area. ■ Cover vent and surrounding area with interim cover soil within four hours.
■ Ground subsidence	■ If required, expand existing exclusion zone to include identified hot spot area. ■ Cover subsidence and surrounding area with interim cover soil within four hours.
■ Surface fire	■ Implement site management controls. ■ For small-scale fires use on-site resources to douse the flames, cool the burning material with water and/or cover soils. ■ For larger-scale fires implement site emergency response procedures and call emergency services.
■ Smoke and odours outside Stage 2 footprint	■ Investigate potential sources and implement controls above where required. ■ For unknown or diffuse sources commence more detailed inspection and investigation program and commence ongoing air quality monitoring program until conditions improve.

5.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled – “Important Information Relating to this Report”, which is included in Appendix C. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how is can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

Signature Page

WSP Australia Pty Limited

Amy MacGregor
Civil Engineer

James Begg
Principal Engineer, Waste Management

AGM/JSB/ATG/BD/agm

A.B.N. 64 006 107 857

https://golderassociates.sharepoint.com/sites/162689/project files/6 deliverables/002-r hotspot remediation action plan/ps132331-002-r-reva - sbwmf stage 2 hotspot remediation action plan.docx

APPENDIX A

NTEPA Authorised Officer Direction Notice

APPENDIX B

Initial Site Inspection and Recomendation Advice

APPENDIX C

Important Information



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TECHNICAL MEMORANDUM

DATE 02 November 2022 **Reference No.** PS132331-008-M-Rev0

TO Nick Fewster
City of Darwin

CC Shane Coleman

FROM Amy MacGregor **EMAIL** **amy.macgregor@wsp.com**

STAGE 2 INERT WASTE LANDFILL SUBSURFACE HOTSPOT, INTERIM OPTIONS UPDATE, SHOAL BAY WASTE MANAGEMENT FACILITY

1.0 INTRODUCTION

The Northern Territory Environment Protection Authority (NT EPA) issued an Authorised Officer Direction Notice to the City of Darwin (Council) on the 19 May 2022 regarding hotspot conditions observed within the Stage 2 Inert Waste Landfill at the Shoal Bay Waste Management Facility. Council has commissioned WSP Australia Pty Ltd (WSP Golder) to provide technical support for investigation and management of the hotspot conditions. Initial drilling investigation and air monitoring programs have been undertaken have been undertaken to assess the potential location and scale of the Active Hotspot(s) and potential impacts to the environment and human health.

Point b) of the NTEPA Authorised Officer Direction Notice requires Council to '*develop a strategy to extinguish any subterranean fires remaining in Stage 2*'.

This Technical Memorandum provides a brief summary of potentially suitable options to manage and mitigate the identified hotspot conditions.

2.0 OPTIONS UPDATE

A brief preliminary options review was provided in the 'Draft SBWMF Stage 2 Hotspot Remediation Action Plan', reference PS132331-002-R-RevA. Short excerpts from Section 3.3 of the Draft Remediation Action Plan have been reiterated in this technical memorandum with more detailed commentary relating to the potential implications to Shoal Bay's future landfill operations based on the implementation of each option.

The following options have been considered:

- Option 1 - Excavate Hotspot Waste and Extinguish.
- Option 2 - Manage and Monitor Hotspot Conditions
  - Potential inclusion - trial new firefighting foam technologies to support containment.

2.1 Excavate Hotspot Waste and extinguish

This option comprises the complete excavation of buried waste hotspots to enable hot/smouldering material to be cooled and smothered using methods such as soil, cover, water application or mechanical breakdown.

This option is generally considered the only methodology proven to achieve full extinguishment of large scale and deep landfill hotspots within a reasonable timeframe. This option, however, needs to be considered in the context of key potential advantages and disadvantages as summarised in Table 1.

Table 1 : Excavate Hotspot Waste and Extinguish

Key Potential Advantages	Key Potential Disadvantages
▪ Proven methodology to abate large, deep waste hotspot conditions. ▪ Full extinguishment of hotspot conditions is expected to support the removal of the following: ▪ Current restrictions to operation of the Stage 2 Inert Waste Landfill. ▪ Potential constraints for the long-term operation and future expansion of Stage 2 Inert Waste Landfill operations.	▪ Likely to disturb and expose ACM that requires controls to protect human health during the handling process. ▪ Likely to disturb and expose smouldering tyres and timber that may spontaneously combust, both within disturbed and undisturbed materials. ▪ Introduction of air from excavations into undisturbed waste can cause the spread of adjacent hotspot conditions at a rate faster than the hotspot extinguishment excavation works. ▪ Likely to disturb and expose smouldering tyres, timber and other smouldering waste materials that may result in significant odour and air quality impacts on-site and off-site. ▪ Large scale excavations may take considerable time and require large-scale hardstand areas and potential alternative waste reburial cells. ▪ Run-off from water cooling hardstands required to be contained and managed as leachate. ▪ Large scale hotspot waste excavations, cooling and reburial are likely incur significant costs.

This option is currently considered to be the only proven strategy to satisfy the Point b) of the NT EPA Notice to extinguish any subterranean fires.

Complete abatement of hotspot conditions would also remove potential associated constraints to the continued operation and expansion of the Stage 2 Inert Waste Landfill, including allowing future installation of geosynthetic lining systems and other necessary waste containment infrastructure.

As noted above; however, that this option has the potential to result in relatively high short term risks to human health and the environment that could potentially be greater than current existing hotspot conditions.

2.2 Manage and Monitor Hotspot Conditions

An option to Manage and Monitor Hotspot Conditions has been identified as an alternative strategy to the option of excavation and extinguishment. As per the description, this option is primarily focused on ongoing management and mitigation of the impact of hotspot conditions rather than seeking active extinguishment.

This option may comprise a combination of management strategies such as construction of improved quality capping layer/cover soils, limiting the size of the waste disposal working face area, and monitoring strategies such as ongoing temperature and periodic air quality monitoring.

Under ideal conditions it is possible; however, that hotspot conditions could fully dissipate over prolonged periods of time. This option needs to be considered in the context of key potential advantages and disadvantages as summarised in Table 2.

Table 2 : Manage and Monitor Hotspot Conditions

Key Potential Advantages	Key Potential Disadvantages
▪ Reduces the disturbance of asbestos containing materials and smouldering wastes and associated risks to human health and the environment. ▪ Reduces costs associated with the excavation, management and disposal of smouldering wastes.	▪ This option is not proven to result in full extinguishment of hotspot conditions. ▪ Full extinguishment of hotspot conditions, if it occurs, may occur over a prolonged period of time. ▪ NTEPA may not consider that this option complies with Point b) of the Authorised Officer Direction Notice. ▪ Continued hotspot conditions may still spread over time into other areas of the Stage 2 Inert Waste Landfill, including wastes placed in the future. ▪ Requires additional expenditure on: ▪ Maintaining a high standard of soil cover over buried waste materials. ▪ Minimising the active working face to reduce pathways for air to enter buried waste materials ▪ Long term active monitoring temperature and air quality of hotspot conditions to identify potential changes or migration into other areas of the Stage 2 Inert Waste Landfill. ▪ Potential works to contain future migration of hotspot conditions. ▪ Given the uncertain risk of future migration of hotspot conditions, this option may require restrictions on: ▪ Future disposal of waste within the current waste landform ▪ Future installation of geosynthetic materials required to support construction of additional capacity within the Stage 2 Inert Waste Landfill. ▪ Loss of planned airspace capacity from the Stage 2 Inert Waste Landfill will require replacement with alternative capacity within the Stage 5/Stage 6 General Waste Cells and/or construction of a new inert waste disposal facility. ▪ It may not be possible to construct future final capping of the Stage 2 Inert Waste Landfill whilst hotspot conditions remain.

The cost for implementation of this option are expected to be initially lower compared to the Excavate Hotspot Waste and Extinguish option; however, ongoing costs will be incurred to support improvement management and monitoring programs. Future spread of hotspot conditions may require active intervention with unknown costs.

As noted above, it is important to understand that adoption of the Management and Monitoring option may restrict current and future waste disposal operations within the Stage 2 Inert Waste Landfill. As a minimum, Council should expect that placement of new waste within active hotspot areas will not be permitted.

It is understood that the planned expansion of the Stage 2 Inert Waste Landfill required the installation of piggyback liner and leachate collection systems. Typical geosynthetic materials used for piggyback liner construction are likely to be significantly damaged and lose their performance capacity in close proximity to hotspot conditions.

Until hotspot conditions are better understood, Council should suspend existing plans for expansion of the Stage 2 Inert Waste Landfill. Long term implementation of this option may require Council to consider relocating the disposal of inert waste to the Stage 5/Stage 6 General Waste Landfill or an alternative disposal facility.

2.3 Trial New Technologies for Hotspot Containment

To support the implementation of the 'Monitor and Manage' option, there is an opportunity to trial the application of new firefighting foam technology to support containment of existing hotspot conditions. The objective is to produce a non-flammable coating that may restrict the further spread of hot spot conditions. Firefighting foam has been used in similar applications for fires in underground coal mines and large above ground stockpiles. We note; however, no documented examples of similar use for landfill hotspots have been identified to date.

The trial would comprise the injection of various firefighting foams into the waste mass and then excavate the injected areas to assess the performance of the foams to coat buried waste material. This option needs to be considered in the context of key potential advantages and disadvantages as summarised in Table 3.

Table 3: Option 3 – Firefighting Foam Trials

Key Advantages	Key Disadvantages
■ Potentially provides an option to contain hotspot conditions within a known area. ■ Potentially limits requirements to disturb buried waste material and impacts associated with: ▪ ACM management ▪ Spontaneous combustion ▪ Significant odours ■ Potentially achieves appropriate human health and environmental protection outcomes using options that are practical, feasible and more cost effective compared to the Excavate and Extinguish option.	■ May not be suitable to containment landfill hotspot conditions. ■ Multiple trials may be required to identify a suitable material and application methodology. ■ May require extended implementation timeframe. ■ May require use of ongoing exclusion zones that may limit ongoing use for waste disposal and restrict planned expansion works. ■ May not be suitable to fully extinguish hotspot conditions.

3.0 NEXT STEPS

- Preparation of a report summarising both the drilling investigation and the temperature monitoring results collected to date.
- Finalisation of the full air quality monitoring report.
- Preparation of an Environmental and Human Health Risk Report documenting qualitative risk assessments of the hotspot conditions.
- Preparation of a proposal to continue temperature monitoring of hotspot conditions.

Golder Associates Pty Ltd

Amy MacGregor
Senior Civil Engineer

James Begg
Technical Executive, Waste Management

AGM/JSB/agm

https://golderassociates.sharepoint.com/sites/162689/project files/6 deliverables/008-m preliminary options assessment/ps132331-008-m-rev0 preliminary options assessment.docx

TECHNICAL MEMORANDUM

DATE 17 November 2022 **Reference No.** PS132331-010-M-Rev1

TO Mr Shane Coleman
City of Darwin

FROM Amy MacGregor **EMAIL amy.macgregor@wsp.om**

PROGRESS UPDATE – NOVEMBER 2022, STAGE 2 INERT LANDFILL HOTSPOT PROGRAM, SHOAL BAY WASTE MANAGEMENT FACILITY, DARWIN

Introduction

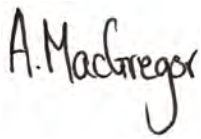
The Northern Territory Environment Protection Authority (NTEPA) issued an Authorised Officer Direction Notice to the City of Darwin on the 19 May 2022 regarding hotspot conditions observed within the Stage 2 Inert Landfill at the Shoal Bay Waste Management Facility.

Attachment A of this technical memorandum provides a brief update on progress to date and current program to address required actions nominated in the Direction Notice.

Important Information

Your attention is drawn to the document titled – "Important Information Relating to this Report", which is included in Attachment B of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations WSP Golder has under the contract between it and its client.

WSP GOLDER



Amy MacGregor
Senior Civil Engineer



Bruce Dawson
Technical Director – Environment

AGM/BED/hn

Attachments: A – NTEPA Direction Notice Progress and Program Update
B – Important Information

https://golderassociates.sharepoint.com/sites/162689/project files/6 deliverables/010-m ntepa notice update/ps132331-010-m-rev1 - sbwmf stage 2 landfill hotspot ntepa notice update.docx

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A.B.N. 64 006 107 857

ATTACHMENT A

NTEPA Direction Notice Progress and Program Update

Notice Dates	Notice Direction Actions	Program Actions	Target Program Dates	
			Start	Completion
Item 1: Prevent Environmental Harm				
Immediately	Prevent further waste disposal	Completed (Council/Veolia)	N/A	N/A
	Establishment of exclusion area	Completed (Council/Veolia)	N/A	N/A
Item 2: Suitably Qualified Consultant Support				
15 June 2022	Engagement	Completed (WSP Golder)	N/A	N/A
1 July 2022	a) i. Location and extent of active hotspot areas ii. Location and extent of all hotspot areas iii. Update of exclusion areas	Initial drilling program to identify potential extent and depth of hotspots and install steel monitoring standpipes to support further monitoring. Scope and completion date dependent on initial investigation findings. Monitoring program to identify potential changes hotspot conditions.	23 Aug 2022 Sept 2022	October 2022 Ongoing
15 Aug 2022	b) Strategy to manage/mitigate hotspots: i. Methodology and timeframes ii. Site layout plans iii. Environmental management plan iv. Environmental monitoring plan v. Emergency response plan	High level review of potential options. Preferred mitigation strategy and associated management plans to be developed at completion of initial investigation program.	July 2022 Oct 2022	Aug 2022 To be confirmed – temperature monitoring shall be ongoing and inform the mitigation strategy.
30 Aug 2022	c) Develop and implement monitoring program: i. Contaminant investigation program ii. Human health and environment risk assessment	Desktop literature review to identify potential contaminants of concern. Preliminary Conceptual Site Model preparation. Initial air quality monitoring program. Review of existing water quality monitoring programs and available data. Undertake Human health and environment risk assessments. Assess and implement additional air monitoring and/or changes to existing water quality monitoring programs as required.	Aug 2022 Aug 2022 29 Aug 2022 Nov 2022 Nov 2022 Nov 2022	Dec 2022 Dec 2022 Sep 2022 Dec 2022 Jan 2023 Jan 2023

ATTACHMENT B

Important Information

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

Appendix G Incident Register

Item #	Licence Condition	Location	Non-Conformance / Exceedance	Time and date	NT EPA Notified	Actual / Potential Cause	Identified action	No Action / Why?	Date for incident investigation to EPA	Responsible Person	EPA Reference No
1	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay - BeneVap Leachate Ponds	Discharge of 300 litres of leachate to ground at the BeneVap machine.	Between 7:00 am and 7:30 am Saturday the 12th of June 2021	The incident was reported Via the NT EPA hotline at approximately 2:00 pm on the 12th of November 2021	Pump failure of the BeneVap 300 pump.	Replace the BV300 and the pump will be placed in a bunded area to ensure no further spill are possible.	N/A	**25th of June 2021**	Emma Young	
2	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay - western side of Northern Leachate Pond	On the 12 of November during trenching for electrical cable along the western batter of the northern pond leachate began seeping into the base of the trench. It is estimated that approximately 50 litres filled the base of the trench.	Friday the 12 of November 2021	The incident was reported to the NT EPA Pollution Hotline at approximately 2:00 pm on the 12th of November	The potential cause was due to the leachate level in the Northern pond being high. The leachate then wicked between the liner and cover and outside the contained area.	Leachate level in the northern pond was reduced, this immediately prevented any further leachate escape.	N/A	**15th of November 2021**	Emma Young	
3	This notification of non-compliance is made to the NT EPA under condition 26, 27, 29 and 47 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay Stage 2 inert landfill	Veolia staff noticed smoke coming from under the surface of stage 2 landfill on the eastern batter. 8:00 am staff noticed smoke, 8:22 am Veolia management were notified, 8:50 am Veolia management on site, 9:31 am Darwin Fire Station notified but did not attend site, 9:45 am LMS contacted, they informed that there was no gas being extracted from stage 2, 11:48 am City of Darwin notified.	8:00 am Friday the 27th of December 2021	The incident was reported to the NT EPA pollution hotline at Approximately 1:25 pm on the 27th of December 2021	The actual cause is unknow as this part of the landfill had not received waste for approximately 2 years. Possible subterranean fire active for sometime and going un noticed…	Excavating the area in a bid to possibly locate and establish the depth of the fire only exacerbated the fire by allowing oxygen to fuel the fire. It was established that the fire was a considerable distance below the surface. To reduce the impact of the fire, it was decided to fill the excavated hole with wet cover material to smother the fire.	N/A	**27th of November 2021**	Emma Young	
4	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay - Stage 3 and Stage 4 landfills	Leachate breakouts on both stages of the landfill	12:40 pm on the 20th of January 2022. City of Darwin Team Leader notified by NY EPA officers who were on site.	Reported via the Pollution hotline 1:45 pm on the 20th of January 2022 - Reference number **188115017**	High rainfall saturating the landfill batters. No final cap on both stages also a contributing factor.	Restrict leachate from entering stormwater system on site. Transfer leachate to leachate holding system on site via vac truck. Inspect and plan a mechanical intervention to repair breakout on stage 3. Stage 4 engage Golder to inspect and advise possible causes and option to control future breakouts.	N/A	**3rd of February 2022**	Shane Coleman	
5	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay Stage 5, Stage 6A and GWILP	Leachate breakouts on eastern side of Stage 5 ramp, Leachate migrating towards and into Stage 6A, Ground Water Interception Leachate Pond (GWILP) discharging leachate impacted water.	8:30 am on the 21st of January 2022. Weekly site inspection being conducted by Veolia and City of Darwin.	The incident was reported to the NTEPA pollution hotline at 1:20pm on the 21st of January 2022. NT Hotline reference number **18122445**	Eastern side of stage 5, high rainfall causing the batters to be super saturated which contributed to the breakout. Stage 6A, the area where stage 3 and stage 5 intersect being the breakout location. Again, high rainfall, ground saturation are contributing factors. It was noted that there appeared to be a combination of leachate and surface / rainwater from recent rains migrating towards 6A lined cell. GWILP, there was leachate impacted water flowing from the southern pond discharge line. Causal factors - recent rain sitting on the rain covers on top of the leachate ponds may have caused lateral dispersion forcing leachate to exit the pond between the liner and cover.	The stormwater drain was bunded, and 3 of the areas of concern excavated and plugged. Upon further investigation the 4th area of concern was not a breakout. Stage 6A sand bagging has been installed to contain and divert impacted water from entering 6A basin. GWILP, the area has now been bunded to prevent any further environmental impact, the leachate impacted water is being pumped via Vac Truck and returned to leachate storage area.	N/A	**4th of February 2022**	Shane Coleman	
6	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay Stage 5	Leachate breakout on the western batter of stage 5	9:00 am 2nd of February 2022	Reported Via the NT EPA hotline @3:36 pm followed by a section 14 Incident Notification	High internal levels of leachate as well as saturated batters from recent rains	As the area is too wet to conduct a mechanical intervention, Veolia will install a absorbent boom below the bleed to prevent leachate migrating towards the stormwater drain.	N/A	**16th February 2022**	Shane Coleman	
7	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay stage 6B surface water discharge point	Water samples taken from the surface water discharge point on stage 6B indicated the water had exceedances based on attachment 3 of the current EPL188-03.	3:00 pm 4th of February 2022	Reported Via the NT EPA hotline @ 3:20 pm Ref # 18226228. A section 14 notice was also submitted.	Surface contamination being the most likely cause.	The discharge point has been capped to prevent and further release to stormwater.	N/A	**18th February 2022**	Shane Coleman	
8	This notification of non-compliance is made to the NT EPA under conditions 68, 67 and 71 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay water quality exceedances	Water quality results for surface water, groundwater and leachate some of the result exceeded trigger points, value exceedances and guideline exceedances outlined in EPL188-03.	11:14 am 26th January 2022	Reported to the NT EPA Thursday the 3rd of February 2022 via email, also a section 14 was completed on Monday the 7th of February.	All sample results exceedances are most likely contributed to by past practices or event from the Shoal Bay operation.	Operational improvements will continue on site for managing and storing Leachate. Data will also be monitored to ensure historical trends regarding water quality do not deteriorate.	N/A		Shane Coleman	
9	This notification of non-compliance is made to the NT EPA under conditions 68, 67 and 71 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay water quality exceedances	Water quality monitoring data from August 2021 and October 2021 had exceedances in lab results	**Water results were emailed to Sybille by Emma Young on Wednesday the 10th November 2021 4:27pm**	**No formal notification was completed at the time. The exceedances were picked up by the EPA when reviewing the results for August to October.**	All sample results exceedances are most likely contributed to by past practices or event from the Shoal Bay operation.	Operational improvements will continue on site for managing and storing Leachate. Data will also be monitored to ensure historical trends regarding water quality do not deteriorate.	N/A		Emma Young	
10	Non Compliance as per condition 55.1 Surface water as detailed in Attachment 3 not having flow meters against GWILP,GW15, GW16SWStg 1&2 and SW Stage 5.	Various location Shoal Bay landfill Operational area.	No Flow meters installed as per condition 55.1 in attachment 3 of EPL188-03	**Identified by NT EPA in a email dated 11th November 2021 1:42pm from Sybille McPhail**	**No Formal notification was submitted for not having flow meters at various locations**	Flow meters were never installed when the infrastructure was installed / commissioned.	City of Darwin will have flow meters installed in March 2022	N/A	**30th February 2022**	Emma Young	
11	Non Compliance to licence conditions 55.2 not having field parameters in the water testing results for flow of water as per attachments 4 and 5 of the EPL188-03	Various location Shoal Bay landfill Operational area.	No Flow meter records recorded in water data results	**Identified by NT EPA in a email dated 11th November 2021 1:42pm from Sybille McPhail**	**No Formal notification was submitted for not having flow meters at various locations**	Flow meters were never installed when the infrastructure was installed / commissioned.	City of Darwin will have flow meters installed in March 2022	N/A	**30th February 2022**	Emma Young	
12	Non Compliance with condition 55.3 as detailed in Attachment 6 of the EPL188-03	Shoal Bay Various locations	No Flow meter records recorded in water data results DW2, DW3, DW5, Dw6, DW7, DW8, TC Sump and LMPO2	**Identified by NT EPA in a email dated 11th November 2021 1:42pm from Sybille McPhail**	**No Formal notification was submitted for not having flow meters at various locations**	Flow meters were never installed when the infrastructure was installed / commissioned.	City of Darwin will have flow meters installed in March 2022	N/A	**30th February 2022**	Emma Young	
13	Non compliance due to dispositional monitoring data occurring out of cycle in March (for January 2021). Dispositional monitoring the happen bi annually (January and July)	Shoal Bay Landfill	Dispositional monitoring happened outside of licence conditions (March 2021) Dispositional monitoring to happen bi annually January and July each year.	**Identified by NT EPA in a email dated 11th November 2021 1:42pm from Sybille McPhail**	**No Formal notification was submitted for not having flow meters at various locations**	Change over between contractors doing the sampling for City of Darwin.	Cardno are scheduling as per EPL188-03 licence conditions.	N/A		Emma Young	
14	Non Compliance with Condition 60, not all sampling point sampled with to record or attempts to return and get samples.	Shoal Bay Landfill	No record in the sampling data of further attempts where taken to take samples from areas initially inaccessible .	**Identified by NT EPA in a email dated 11th November 2021 1:42pm from Sybille McPhail**	**No Formal notification was submitted for not having flow meters at various locations**		Sampling contractor are aware of the expectations in condition 60 in EPL 188-03 and will action	N/A		Emma Young	
15	Non Compliance with Condition 50, late lodgement of Annual Environmental Audit report with NT EPA.	City of Darwin	Annual Environmental Audit Report not being submitted with 2 month from when the NT EPA approving the environmental scope on 9 November 2021.	15th February 2021	The final Audit was lodged with NT EPA on the 14th of February 2021 at 11:55 am	There was a delay in the NT EPA approving the terms of Reference which was only received on the 21st of December 2021.	Ensure all aspects pertaining to the Annual Audit are in place to prevent future avoidable delays.	N/A		Emma Young	
16	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	GWILP and Stage 5 tanks Shoal Bay	The northern pond has reached capacity, leachate is discharging at GWILP. Stage 5 tanks are being used to store leachate in o try and minimise further environmental harm.	25th February 2022	Reported to the NT EPA Pollution Hotline at 10.56 am, Section 14 was also emailed to Waste NT EPA at 4.22 pm	Leachate pond at capacity, use of storage tanks on stage 5 a necessity to minimise environmental harm.	Arrange for leachate to be removed from site and stored at a licenced facility short term.	N/A	**11th March 2022**	Shane Coleman	
17	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Leachate went to ground 20-50 litres on the western side of the Northern leachate pond	A leachate spill on the ground at the inflow to the northern pond while decanting leachate from GWILP.	24th February 2022	Reported to the NT EPA Pollution hotline on the 24th of February and a section 14 emailed to the EPA	Northern pond reaching capacity.	Stopped decanting leachate into that pond, changed to the southern pond.	N/A	**10th March 2022**	Shane Coleman	

Item #	Licence Condition	Location	Non-Conformance / Exceedance	Time and date	NT EPA Notified	Actual / Potential Cause	Identified action	No Action / Why?	Date for incident investigation to EPA	Responsible Person	EPA Reference No
18	This notification of non-compliance is made to the NT EPA under conditions 68, 67 and 71 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay Water Quality Exceedances	Water quality results for surface water, groundwater and leachate some of the results exceeded trigger points, value exceedances and guideline exceedances outlined in EPL188-03.	25th February 2021	Reported to the NT EPA via email as prescribed on Condition 68 at 8:51 an on the 28th of February followed by the non-conformance notification also on the 28th of February 2022.	Exceedances are inline with historical data for the Shoal Bay site. Past practices may have contributed to exceedances.	Operational improvements will continue on site for managing and storing Leachate. Data will also be monitored to ensure historical trends regarding water quality do not deteriorate. Review of the licence trigger values to see they are suitable for the environment being sampled.	N/A		Shane Coleman	
19	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	GWILP Shoal Bay Landfill	Leachate has escaped from the GWILP which was identified by NT EPA officers during a site visit.	28th of February 2022	A Section 14 notification sent to the NT EPA as well as notifying the NT EPA Pollution Hotline at 1.23pm	The containment bund has overflowed at some stage.	Veolia have ben requested to inspect the site to see if the ground has dried sufficient to construct a second bund wall around the existing containment bund.	N/A	**15th of March 2022**	Shane Coleman	
20	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Western batter of stage 5 at Shoal Bay	Leachate breakouts on the western batter of stage 5 and south eastern toe of stage 5 identified by the NT EPA while on site.	28th of February 2022	A Section 14 notification sent to the NT EPA as well as notifying the NT EPA Pollution Hotline at 1.23 pm	Surface saturation and high levels of internal leachate	Veolia investigating whether they can do a mechanical plug on the individual breakouts or a surface trap to absorb and contain the leachate.	N/A	**15th of March 2022**	Shane Coleman	
21	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Western batter stage 4 and south eastern side stage 3	Leachate breakouts identified on stage 4 and stage 3 batters.	11th March 2022	Section 14 completed and NT EPA hotline notified @ 11:50 am Ref # 1848253.	High levels of internal leachate.	Mechanical repairs are being conducted today to stop the breakouts.	N/A	**25th March 2022**	Shane Coleman	
22	Non-compliance with condition 55, incomplete data in quarterly water sample results by Cardno.	Shoal Bay water quality results	Missing data in quarterly report, flow estimates for surface water and groundwater. Not all required field parameters, frequency and locations have been fulfilled.	10:47 on the 11th of March 2022	NT EPA notified City of Darwin of reg non conformances via email.	Water quality contractor not completing all his obligation regarding water testing.	Cardno have been notified of the expectations and will be monitored to ensure full compliance in future testing. Flow meters will be installed week starting the 21st of March 2022.	N/A	N/A	Shane Coleman	
23	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Western batter of stage 4 close to DW3	Leachate was noticed breaking the surface of stage 4 on the western batter .	7:03 am on the 21st March 2022	NT EPA Hotline notified Ref # 18546429 and a section 14 has been sent to the NT EPA.	Light levels of leachate along the batters of stage 4 could be a contributing factor.	A mechanical repair was tried with little success due to the surface being very wet. A temporary plug was placed over the top and a containment bund installed to manage any leachate that escapes.	N/A	**4th April 2022**	Shane Coleman	
24	Non-compliance with condition 62, BeneVap emission results exceeding the one month threshold to have report to the NT EPA>	BeneVap emissions Shoal Bay	The emission report exceeding the one month threshold to deliver a report to the NT EPA.	Testing was done in January 2022	Email correspondence with NT EPA notifying them of the delay	Due to the extensive suite of tests required and the complexities involved, some of the fields are taking longer than one to deliver results.	The Beneterra group have been notified and are consulting with Assured Environmental to see if testing can be expedited.	N/A	**N/A**	Shane Coleman	
25	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Southern eastern corner north of TC Sump on stage 3	Leachate pooling on the surface of stage 3	2.15pm Wednesday the 23rd of March 2022.	EPA Hotline notified 3.22 pm on 23rd of March 2022 and a section 14 completed and sent to NT EPA	Air supply to the TC Sump pump was not receiving air.	Air supply was reconnected and pump inspected for operation.	N/A	**6th of April 2022.**	Shane Coleman	
26	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Northern leachate pond pipe area	A backflow incident when the operators vacuum truck was transferring leachate to the northern leachate pond	4pm Friday 25th March 2022	EPA Hotline notified 4:45pm on 25th of March 2022 and a section 14 completed and sent to NT EPA. No call back was received.	Capillary action inside the infeed portal to the northern pond.	Spill was contained immediately. Absorption pads were initially put down. Soil was used to soak up the liquid that was spilled. The leachate contaminated soil was then scrapped up and placed into a contained storage bin.	N/A	**8th of April 2022.**	Shane Coleman	
27	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Southern Leachate Pond	Southern leachate pond close to reaching the 600mm freeboard needed for the pond.	4th of April 2022 at 7:30 am	EPA hotline notified at 10:58am on the 4th of March 2022.	High levels of leachate being pumped from stage 3&4.	Switch inflow to the northern pond.	N/A	**18th April 2022**	Shane Coleman	
28	This notification of non-compliance is made to the NT EPA under conditions 68, 67 and 71 of the City of Darwin's Environment Protection Licence (EPL 188-03).	GWILP Water Quality exceedance	Groundwater sampled from GWILP had exceedances with licence conditions	30th March 2022	Monday the 4th of April 2022	Groundwater contaminated with Leachate from leachate ponds	Reduce the levels of leachate in both holding ponds	N/A	**18th April 2022**	Shane Coleman	
29	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Leachate transfer line between stage 3 and stage 2	Leachate went to ground from infrastructure failure.	14th April 2022	Thursday the 14th of April 2022	Connecting valve join two lengths of poly pipe failed causing leachate to go to ground.	The pumps were turned off, and the pipe repaired. The onsite vac truck was used to clean up leachate.	N/A	**28th of April 2022**	Shane Coleman	
30	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Entry to Southern Leachate pond	20-50 litres of leachate went to ground at the entry point to the Southern pond.	10th May 2022 at 11:00 am	10th of May 2022 at 12:20pm	The Benaterra return line migrated up the infeed allowing leacahte to discharge onto the concrete pad.	Both Benevap machines were turned off and area isolated. The return line was reinserted back into the injection point to the pond	N/A	**24th of May 2022**	Shane Coleman	
31	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Construction site for Leachate treatment plant	Fire in waste skip	4th of May 2022 at 4.05pm	4th of May at 4:43 pm	Unknown what actually caused the fire.	Toolboxed withj all contractors and staff to monitor what is deposited into the bins.	N/A	**19th of May 2022**	Shane Coleman	
32	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Green waste mulching site	Fire in mulch pile	16th of September 2022 at 2.40 pm	16 September 2022 at 3.16 PM	fire appeared to have occured from within the mulch pile since not external source were identified	The fire was extinguised with 20 KL of water and the mulch pile was laid out.	N/A	**26-Sep-22**	Pema Dorji	
33	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	leachate pond	hydraulic fluid spill	1st Nov 22 at 3.30 PM	1st Nov 22 at 4.10 PM	backhoe blew a hydraulic hose during operation releasing 2-5 L of fluids	the fluid was contained using spill pads and disposed	N/A	**11-Nov-22**	Pema Dorji	
34	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Northern leachate pond area	Concentrate leachatespill	21 Nov 2022 at 9.00 AM	21 Nov 2022 at 2.30 PM	concentrate leachate spill due to siphoning from the influent lines even when the pumps were shut	solenoid valve installed on the influent lines so that such incidents don't occur again.	N/A	**29-Nov-22**	Pema Dorji	
35	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Shoal Bay	Water quality exceedences	25 Nov 2022 at 10.48 am	25 Nov 2022 at 11.54 am		GWILP water is collected and pumped back into the leachate pond	N/A	**25-Nov-22**	Pema Dorji	
36	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	groundwater interception holding tank (GW	Groundwater released due to tank overflow	2 Dec 2022 at 3.45 PM	2 Dec 2022 at 5.22 PM	The groundwater tank filled faster than the transfer pump could transfer, causing groundwater spill outside the holding tank	both flow control valves were isloated, pump upgraded	N/A	7-Dec-22	Shane Coleman	
37	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Stage 6A	fire in waste during waste disposal at Stage 6A	5 Dec 2022 @ 4.10 PM	no notification to EPA	the waste caught fire when the waste from transfer station bin .4 was disposed at Stage 6.	The fire was extinguised with water	N/A	14-Dec-22	Pema Dorji	
38	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Northern borrow pit and LTP area	Treated leachate overflow from LTP wetland to borow pit	5 Jan 2023 @ 10.30 AM	5 Jan 2023 at 4.17 PM	The treated leachate overflow from LTP wetland due to excess dilution from rain.	The overflow volume and water quality are being monitored.	N/A	16/01/2023	Pema Dorji	
39	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Stage 3 (eastern batter)	leachate seepage	16 jan 2023 at 7 AM	16 Jan 2023 at 12.12 pm	leachate seepage on stg 3 eastern batter	the seepage is contained in a bund in the drainage and will be collected and tr	N/A	24/01/2023		
40	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	temporory Tank 3 near the weighbridge	lachate impacted rainwater spill	24/02/2023 at 8.30 AM	24/02/2023 at 12.17 PM	submerged airvent which let rainwater get inot the tank	spill contained within the bund, transferred impacted rainwater to the leachat	N/A	3/09/2023	Pema Dorji	
41	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Temporory Tank 1 at Stage 1	leachate impacted rainwater spill	27/02/2023 at 11 AM	27/202/2023 at 12.07 PM	Spill during the leahcate transfer from Tank 3 to tank 1, actual cause under investigation	all the spill collected and transferred to the leachate ponds	N/A	16/03/2023	Pema Dorji	PRL11497

Item #	Licence Condition	Location	Non-Conformance / Exceedance	Time and date	NT EPA Notified	Actual / Potential Cause	Identified action	No Action / Why?	Date for incident investigation to EPA	Responsible Person	EPA Reference No
42	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	DW2 pump (north-western corner of stg 4	leachate spill due to pump failure	28/02/2023 at 11.37 AM	27/202/2023 at 4.45 PM	DW2 pump failure	spill contained and transferred to the leachate ponds	N/A	16/2/2023	Pema Dorji	PRL11502
43	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Stage 3 (eastern batter)	leachate seepage	2/3/2023 at 4.55 PM	03/03/2023 at 2.22 PM	leachate seepage on stg 3 eastern batter	spill contained and transferred to the leachate ponds	N/A	16/3/2023	Pema Dorji	PRL11519
44	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	stage 6 & stage 3 interface	leachate seepage	10/03/23 at 12.11 PM	10/03/2023 at 2.27 PM	Leachate seepage	spill contained and transferred to the leachate ponds	N/A	23/3/2023	Pema Dorji	PRL11546
45	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Treated leachate borrow pit	Treated leachate overflow on the spillway	8/3/2023 at 10.45 AM	9/3/2023 at 10.00 AM	treated leachate overflow from spillway	bunded the spill way to stop the flow	N/A	20/03/2023	Pema Dorji	PRL11533
46	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Northern leachate pond area	concentrate leachate spill	28/04/2023 at 7.45 am	28/04/2023 at 1.59 pm	Overflow switch failure	manual switchoff of the machine, overflow containment, remediation	N/A	5/05/2023	Pema Dorji	PRL11652
47	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Temporory Tank 1 at Stage 1	leachate spill due to lid compromise	4/5/2023 at 2.29 pm	5/5/2023 at 1.22 pm	lid compromise	switch off pump, clean up mess & investiate	N/A	19/5/2023	Pema Dorji	PRL11672
48	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Green waste mulching site	Mulch fire	06/08/23 at 7 am	06/08/2023 at 8.28 am	internal combustion	fire extinguished with water, isolation of the mulch on fire	N/A	8/10/2023	Pema Dorji	
49	This notification of non-compliance is made to the NT EPA under condition 26, 27 & 29 of the City of Darwin's Environment Protection Licence (EPL 188-03).	Green waste mulching site	Mulch fire	22/08/2023 at	22/08/2023 at 4.09 pm	internal combustion	fire extinguished with water, rotation of stockpile to remove excess heat	N/A	9/04/2023	Pema Dorji	PRL11928

Log of Fires Shoal Bay Landfill as per Condition 25 of EPL188-03

Item#	Date	Time	Date and time fire was reported	Condition 25.1 Time and Date fire reported	Condition 25.2 Circumstances which ignited the fire	Condition 25.3 Time and date the fire ceased, burnt out or extinguished	Condition 25.4 Location of Fire on premises	Condition 25.5 Prevailing weather conditions	Condition 25.6 Observation regarding smoke direction and dispersion	Condition 25.7 Amount of waste combusted by the fire	Condition 25.8 Action taken to extinguish the fire	Condition 25.9 Measures to reduce the risk of further fires
1	10/8/22	7:11:00 AM		Wednesday the 10th of August 2022 at 7:11 am	Unknow the investigation failed to reveal an ignition source	The fire was extinguished on Wednesday the 10th of August at approximately 8:15 am	Mulch piles Shoal Bay	Still weather slight wind from the east towards the west, sunny day.	Smoke was rising straight up them drifting to the west.	2m3 of mulch was burnt	Onsite water truck and Veolia team extinguished the fire	Monitor mulch piles ensure that no smoking is adhered to in this area.
2	26/8/22	6AM		Thursday the 26th of August 2022 6:00 am	Unknown, possibly deliberately lit outside the landfill boundary	The fire was still smouldering around the perimeter of Shoal Bay till Friday the 26th of September the mulch fire was extinguished within three (3) hours of starting.	The western boundary outside the landfill was burning causing embers to drift onto the mulch piles and ignite.	Easterly winds, warm dry day with no rain	Smoke dispersion was mainly towards the west of Shoal Bay heading towards Leanyer.	$3m^3$ of mulch, however many hectares of wetland were burnt.	Backburning as well as local fire service units were used. Veolia also used the water cart to help with extinguishing the fire.	Continue to conduct annual fire reduction burns as well as managing the fire breaks around Shoal Bay Landfill
3	5/8/22	1:00:00 PM		5th September 2022 at 1:00pm	Flare ignited in the waste	5th of September 2022 at 1:10 pm	Stage 6A putrescible waste cell	South Easterly winds sunny dry day no rain.	Very minimal smoke	Nothing of any significant volume - negligible	The flare was smothered using cover material on site at stage 6A	The area will be monitored for more flares, batteries know to create fires in landfills.
4	6/9/22	9:25:00 AM		6th September 2022 at 9.25 am	Flare ignited in the waste	6th September 2022 at 9.35 AM	Stage 6A putrescible waste cell	South Easterly winds sunny dry day no rain.	Minimal smoke	Negligible	flare was smothered with available cover material	Area monitored for any further fire activity
5	9/8/22	10.00 AM		8th September 2022 at 10.00 AM	Unkown ingition source	8th September 2022 at 10.15 AM	Stage 6 A	South Easterly winds sunny dry day no rain.	Minimal smoke	Negligible	Smothered with available cover material	Area monitored for any further fire activity
6	13/9/22	3.00 PM		13 September 2022 at 3.00 PM		13 September 2022 at 3.15 PM	Stage 6 A	West	Minimal smoke	Negligible	Smothered with available cover material	Area monitored for any further fire activity
7	16/09/22			16 Sept 2022 at 2.40 PM	Fire started in the waste, not external source identifed	16 September 2022 at 3.10 PM	Mulch piles Shoal Bay	Westerly	Smoke travelling westerly	Negligible	extinguished with water and the pile was laidout	Areas was monitored overnight
8	24/10/2022	3.30 PM		24 Oct 2022 at 3.30 PM	Flare ignited in the waste	24 oct 2022 at 3.40 PM	Stage 6 A	Westerly	smore travelling westerly	Negligible	Smothered with available cover material	Constant monitoring in place
9	18/11/2022	08.00 AM		18/11/ 2022 at 08.00 AM	flare dischare on tipping area	18/11/2022 at 08.15 AM	Stage 6A putrescible waste cell	Unknown	unknown	negligible	smotherred with dozer	Constant monitoring in place
10	20/11/2022	08.30 AM		20/11/2022 at 08.30 AM	flare dischare on tipping area	20/11/2022 at 08.40 AM	Stage 6 A	south easterly	south easterly	negligible	smotherred with dozer	Constant monitoring in place
11	22/11/2022	7.40 AM		22/11/2022 at 7.40 AM	flare or battery ignition on tipping area	22/11/2022 at 7.50 AM	Stage 6 A	No wind	No specific direction	Negligible	smotherred with dozer	Constant monitoring in place
12	1/9/23	8:00 AM		9/1/2023 at 8 AM & 10 AM	2 fales ignited within two hours of eachother	9/1/2023 at 10.15 AM	Stage 6 A	windy	south easterly	negligible	smothered with dirt	Constant monitoring in place
13	1/10/23	12:00 PM		10/1/2023 at 12 PM	flare ignition	10/1/2023 at 12.10 PM	Stage 6 A		south easterly	negligible	smothered with cover soil	Constant monitoring in place
14	18/01/2023	8:00:00 AM		18/01/2023 at 8 AM	flare ignition	18/01/2023 at 8.10 AM	Stage 6 A	dry day with some wind	south easterly	nil	smothered with cover soil	Constant monitoring in place
15	4/3/23	8.30 am		3/4/2023 at 8.30 am	flare ignition	3/4/2023 at 8.40 am	Stage 6 A	No wind		nil	Smothered with available cover material	Constant monitoring in place
16	21/4/2023	9:00:00 AM		21/4/2023 at 9.00 am	flare ignition	21/4/2023 at 9.10 am	Stage 6A	south east	south easterly	nil	Smothered with available cover material	Constant monitoring in place
17	29/04/2023	11.30 am		29/04/2023 at 11.30 am	flare ignition	29/04/2023 at 11.40 am	Stage 6A	No wind	no wind	nil	Smothered with available cover material	Constant monitoring in place
18	30/04/2023	12.00 am		30/04/2023 at 12.00 am	flare ignition	30/04/2023 at 12.10 pm	Stage 6A	south easterly	south easterly	nil	Smothered with available cover material	Constant monitoring in place
19	5/6/23	4:00:00 PM		6/5/2023 at 4 pm	flare ignition	6/5/2023 at 4.10 pm	Stage 6 A	south easterly	south easterly	nil	Smothered with available cover material	Constant monitoring in place
20	23/5/2023	7.15 am		23/5/2023 at 7.15 am	flare ignition	23/5/2023 at 7.25 am	stage 6	south east	south easterly	nil	Smothered with available cover material	Constant monitoring in place
21	28/5/23	12.00 pm		28/5/23 at 12.00 noon	flare ignition	28/5/23 at 12.15 pm	stage6	unknown	unknown	nil	Smothered with available cover material	Constant monitoring in place
22	5/6/23	11.15 pm		5/6/23 at 11.15 pm	marine fire ignition	5/6/23 at 11.25 pm	stage 6	Unknown	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
23	19/6/23	11.15 pm		19/6/23 at 11.15 pm	Unkown ingition source	19/6/23 at 11.25 pm	stage 6	south easterly	south easterly	Negligible	Smothered with available cover material	
24	27/6/23	8.15 am		27/6/23 at 8.15 am	marine fire ignition	27/6/23 at 8.25 am	stage 6	south easterly	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
25	23/6/23	8.15 am		23/6/23 at 8.15 am	marine flare ignition	23/6/23 at 8.25 am	stage 6	north east	north east	Negligible	Smothered with available cover material	Constant monitoring in place
26	28/6/23	2:00:00 PM		28/6/23 at 2 pm	marine flare ignition	28/6/23 at 2.10 pm	stage 6	north east	north east	Negligible	Smothered with available cover material	Constant monitoring in place
27	11/7/23	3.15 pm		11/7/23 at 3.15 pm	flare ignition	11/7/23 at 3.20 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
28	12/7/23	7.45 pm		12/7/23 at 7.45 pm	flare ignition	12/723 at 7.50 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
29	20/7/23	1.00 pm		20/7/23 at 1 pm	flare ignition	20/7/23 at 1.10 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
30	22/7/23	12.51 pm		22/7/23 at 12.51 pm	external bushfire	22/7/23 at 1.00 pm	south-eastern side of the landfill	south easterly	south easterly	Negligible	Monitored by NT Fire services & water spray	Constant monitoring in place
31	24/07/23	12.00 pm		24/7/23 at 12.00 pm	flare in tipface	24/7/23 at 12.10 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place

Log of Fires Shoal Bay Landfill as per Condition 25 of EPL188-03

Item#	Date	Time	Date and time fire was reported	Condition 25.1 Time and Date fire reported	Condition 25.2 Circumstances which ignited the fire	Condition 25.3 Time and date the fire ceased, burnt out or extinguished	Condition 25.4 Location of Fire on premises	Condition 25.5 Prevailing weather conditions	Condition 25.6 Observation regarding smoke direction and dispersion	Condition 25.7 Amount of waste combusted by the fire	Condition 25.8 Action taken to extinguish the fire	Condition 25.9 Measures to reduce the risk of further fires
32	26/07/23	12.00 pm		26/7/23 at 12.00 pm	marine flare ignition	26/7/23 at 12.10 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
33	8/6/23	6.30 am		6/8/23 at 6.30 am	fire from within the mulch pile	6/8/23 at 1 pm	Greenwaste area	south east	south easterly	20 cum	used water spray to supress the fire	Constant monitoring in place
34	8/7/23	4.30 pm		7/8/23 at 4.30 pm	fire from within the mulch pile	6/8/23 at 4.45 pm	Greenwaste area	south east	south easterly	Negligible	water spray to suppress the fire	Constant monitoring in place
35	8/8/23	12.40 pm		08/08/23 at 12.40 pm	disposed battery	08/08/23 at 12.50 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
36	17/08/23	8.00 am		17/08/23 at 8 am	disposed battery	17/8/23 at 8.10 am	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
37	9/8/23	4.30 pm		8/9/23 at 4.30 pm	phone battery or similar	8/9/23 at 4.40 pm	stage 6	south east	south easterly	Negligible	Smothered with available cover material	Constant monitoring in place
38	4/09/2023	9.30 am		11/8/23 at 9.30 am	disposed battery	4/9/23 at 9.40 am	stage 6	nil	nil	Negligible	Smothered with available cover material	Constant monitoring in place
	6/09/2023	7.20 am		11/8/23 at 7.20 am	disposed battery	6/9/23 at 7.30 am	stage 6	mil	nil	Negligible	Smothered with available cover material	Constant monitoring in place