A: Environmental Evaluation Report for Requirement 8 on STAT1304

PFAS Detailed Site Investigation

Weipa and Andoom Mining Areas, Western Cape York Peninsula, Queensland

RTA Weipa Pty Ltd

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PFAS Detailed Site Investigation, Weipa and Andoom Mining Areas, Western Cape York Peninsula, Queensland

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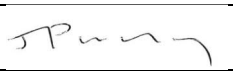
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Abbreviations

Glossary	
AFFF	Aqueous film forming foam
AHD	Australian height datum
AHEQ	Andoom Heavy Equipment workshop
ANZECC	Australia New Zealand Environmental Conservation Council
ASC NEPM	Assessment of Site Contamination National Environment Protection Measure 1999 (as amended 2013)
ATC	Alcohol type concentrate
ASLP	Australian standard leaching potential
COPC	Contaminants of potential concern
CSM	Conceptual site model
DEHP	Department of Environment and Heritage Protection
DES	Department of Environment and Sciences
DO	Dissolved Oxygen
DQOs	Data quality objectives
DSI	Detailed site investigation
EC	Electrical Conductivity
ECF	Electrochemical fluorination
ELN	Evans Landing North
ELN	Evans Landing South
EPP	Environmental Protection Policy
ERA	Ecological Risk Assessment
EVL	Evans Landing
EWHEQ	East Weipa Heavy Equipment Workshop
F&R	Fire & Rescue
FSANZ	Food Standards Australia and New Zealand
GME	Groundwater monitoring event
HEPA	Heads of Environmental Protection Agencies
HEQ	Heavy equipment workshop
HHRA	Human Health Risk Assessment
HDPE	High density polyethylene
IL	Investigation level
ITRC	Interstate Technology and Regulatory Council
LOR	Limits of reporting
mbgl	Metres below ground level
mbtoc	Metres below top of casing
ML	Mining Lease

Glossary	
NATA	National Association of Testing Authorities
NDD	Non-destructive drilling
NEMP	National Environmental Management Plan
NEPC	National Environment Protection Council
NMI	National Measurement Institute
ORP	Oxidation Reduction Potential
PFAA	Perfluoroalkyl acids
PFAS	Per- and poly-fluorinated alkyl substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutane sulfonic acid
PFHpA	Perfluoroheptanoic acid
PFHpS	Perfluoroheptane sulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanesulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PFPeA	Perfluoropentanoic acid
PFPeS	Perfluoropentane sulfonic acid
POP	Persistent organic pollutant
PSI	Preliminary site investigation
QA/QC	Quality assurance / quality control
QWQG	Queensland Water Quality Guidelines
REMP	Receiving Environment Monitoring Program
RTAW	Rio Tinto Alcan Weipa
RWW	Railway Workshop
SAQP	Sampling analysis and quality plan
SES	State Emergency Services
SPR	Source pathway receptor
SPQ	Single Persons Quarters
TDS	Total dissolved solids
TOPA	Total oxidisable precursor assay
UCL	Upper Confidence Level
USCS	Unified soil classification system
WA	Weipa Airport
WTA	Weipa Town Authority
6:2 FTS	6:2 Fluorotelomer sulfonic acid

Executive Summary

Background and Objectives

AECOM Australia Pty Ltd (AECOM) was engaged by RTA Weipa Pty Ltd (RTAW) to deliver a detailed site investigation (DSI), specifically targeting per- and poly- fluoroalkyl substances (PFAS) in the Weipa and Andoom bauxite mining areas located on mining lease 7024, 'the site', on Western Cape York Peninsula in Queensland. The areas under investigation, the 'investigation areas', consist of land used for operational purposes within the Andoom and East Weipa mining leases, the adjoining 'off-site' land areas and the receiving environment that includes the Mission and Embley River catchments. The residential area of Weipa is referred to in this report as Weipa Township.

AECOM understands that RTAW's overall objective is to understand the nature and extent of the identified PFAS impact and to address Requirement 8 of the DES *Notice to conduct or commission an environmental evaluation*, dated 7 September 2018 (the 'Notice') Reference 101/0008738, CR84931, STAT1304, which was:

> *Submit to the department a Detailed Site Investigation (DSI) report prepared in accordance with Assessment of Site Contamination (ASC) National Environmental Protection Measure (NEPM). Notwithstanding ASC NEPM, the report must:*
>
> *a. Delineate the lateral and vertical extent of contamination at the premises and adjoining impacted land;*
>
> *b. Include an updated Conceptual Site Model (CSM); and*
>
> *c. Where environmental harm has been identified, include remediation and management options to address the harm.*

Scope of Works

The DSI has characterised soil, groundwater, surface water and sediment targeting six potential primary source areas identified in the preliminary site investigation (PSI) (Golder, 2018a). These were: Andoom and Easy Weipa Heavy Equipment Workshops (HEQ), Lorim Point Fire & Rescue facility, Evans Landing, Weipa Airport and the Railway Workshop. Following concerns from DES, the DSI also targeted one of the secondary source areas identified (Evans Landing landfill). Collectively, the DSI included:

- the installation of 29 new groundwater monitoring bores to assist with the delineation of groundwater impacts
- the advancement of 43 shallow soil bores to characterise soil within the potential primary source areas
- the collection of groundwater samples from the 29 new and 63 existing groundwater monitoring wells and abstraction bores to provide latest groundwater quality at locations around the potential primary source areas, Evans Landing landfill and at Weipa Township
- the collection of 53 surface water and 16 sediment samples from the Embley River and Beening Creek including samples collected during dry (November 2018) and wet (February 2019) seasons and at high and low tide conditions
- the collection of ten surface water and nine sediment samples from wash bay / pads and downstream locations at the Andoom and East Weipa HEQ
- hydrogeological testing to estimate hydraulic conductivity parameters.

This DSI report considers the results of all PFAS environmental investigations conducted since 2017. This includes the results of a soil investigation in 2017 (reported in Golder, 2018a), groundwater monitoring of existing abstraction bores and groundwater monitoring wells in the period 2017 to 2018 (reported in Golder, 2018a) and the results of aquatic biota sampling (83 samples) collected from the creeks and rivers in 2018 (reported in Golder, 2018c).

Conclusions

The report is considered to meet the overall objective of the DSI, which is to understand the nature and extent of the identified PFAS impact and to address Requirement 8 of Notice STAT1304. The following conclusions are made addressing the requirements as described in the Notice.

Extent of PFAS in Soil

The soil investigations in 2017 and 2018 have identified the presence of areas of soil with locally higher PFAS concentrations (above ecological guideline levels for industrial landuse) in shallow soil at three of the potential primary source areas (Andoom HEQ, Lorim Point and East Weipa HEQ). The soil samples were collected from locations across the open areas at these facilities. PFAS concentrations in 11% of the samples exceeded the ecological guideline level for industrial landuse (maximum of 2.5 mg/kg in a soil sample from Lorim Point), however, none of the soil sample concentrations exceeded human health guidelines levels for industrial landuse.

The results indicate localised discrete areas of PFAS are present in soil at these three facilities. Results indicate the higher concentrations of PFAS were detected in near surface soil. Relatively minor PFAS impacts (close to or below laboratory limit of reporting) were detected in soil samples from across Weipa Airport and the Railway Workshop. The results in these source areas are not considered to be consistent with large sources of PFAS in soil. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas.

Extent of PFAS in Groundwater

Areas of groundwater impacted by PFAS have been detected at sampling locations hydraulically down-gradient of all six potential primary source areas and also down gradient of Evans Landing landfill (a secondary source area). Fluorotelomers were detected at hydraulically up-gradient and cross-gradient locations at all the potential primary sources areas. The distribution of the different compounds is considered to relate to the historical use of different types of firefighting foams in different areas of the site.

Groundwater samples from Lorim Point had PFAS groundwater concentrations (maximum of 4.1 µg/L sum of perfluorohexanesulfonic acid (PFHxS) and perfluorooctanesulfonic acid (PFOS) at LPI_MW08 in July 2018) approximately one order of magnitude higher than the other six potential primary source areas. The source area with the next highest sum of PFHxS and PFOS concentration was Evans Landing (0.7 µg/L in ELS_MW18). Groundwater concentrations in at least one monitoring well from each potential primary source area have exceeded the adopted human health drinking water and ecological guideline levels, however the monitoring wells are not used for potable purposes. There were no exceedances of human health guideline levels for groundwater samples from abstraction bores.

The lateral extent of sum of PFHxS and PFOS in groundwater is considered to be suitably characterised at all potential primary source areas. Some data gaps have been identified for hydraulically down- and cross-gradient locations at Andoom and East Weipa HEQs and the Railway Workshop.

Due to the limited groundwater dataset (typically only one or two rounds of data from the monitoring wells, which were first sampled in 2018), in most cases there are insufficient data to establish trends in groundwater concentrations and the effect of seasonality. A larger groundwater dataset is available for potable abstraction bores[1] (up to six rounds of sampling), showing steady concentrations that are below the drinking water guideline level.

Extent of PFAS in Surface Water and Sediment

PFAS impacts were detected above the surface water guideline level for the 99% protection of fresh/marine water species at near shore areas along Embley River adjacent to Evans Landing (maximum of 0.004 µg/L PFOS) and Lorim Point (maximum of 0.02 µg/L PFOS) with higher PFAS

[1] Water supply bores have been monitored more frequently since 2017 because, consistent with the National Environmental Management Plan (HEPA and DoEE, 2018), greater priority has been placed at this stage of the program on the protection of human health since groundwater beneath the Site is used supply potable/drinking water to the Site and the Weipa Township/community.

concentrations detected during the wet season, which is likely to be related to higher PFAS flux migrating offsite into the near shore environment. There were no exceedances of adopted human health guideline level for recreational use of surface water.

No offshore PFAS impacts were detected in surface water. PFAS impacts (maximum 0.002 µg/L PFOS) were detected above the surface water guideline level for the 99% protection of fresh/marine water species in surface water sampling locations collected during dry and wet seasons along Beening Creek.

Surface water and sediment samples collected from wash bay/pads at Andoom and East Weipa HEQ had elevated PFAS concentrations that exceeded the surface water guideline level for the 99% protection of fresh water species, and these locations are considered to be localised sources of PFAS. PFAS was detected in downstream sampling locations (located approximately 30 m downstream), at lower concentrations compared to the washpad/bay outlets. This indicates the extent of the surface water and sediment impacts may extend beyond the locations of the downstream sampling points. There were no exceedances of adopted human health for recreational use of surface water.

Conceptual Site Model

Based on the results of this investigation, the conceptual site models for the Mission River and Embley River catchments initially developed in the PSI (Golder 2018a) and updated in the Interim Risk Assessment (AECOM, 2018b) have been refined. This DSI has obtained additional characterisation data for all six potential primary source areas and one secondary source area identified in the PSI. The detection of PFAS in soil, groundwater, surface water and sediment at all the areas targeted in this investigation indicates that all seven areas are local sources of PFAS.

Potential migration mechanisms for PFAS were identified to be through infiltration to groundwater and dispersion via groundwater flow, overland surface water run-off and surface water and sediment transport in creeks and rivers. Other important potential migration pathways include leaching of soil impacted by PFAS, excavation and relocation of soil impacted with PFAS and leaching of buried waste in landfills.

The report has identified that seasonal changes at the site appears to affect the distribution of contamination in near shore surface water, with relative higher PFAS concentration detected during the wet season. It is speculated that during the wet season, higher rainfall and associated surface water runoff could potentially mobilise PFAS contaminants in near-surface soils with run-off into drainage channels, creeks and rivers.

The potential receptors identified through this investigation include personnel who work at the site, users of abstracted groundwater, recreational users of nearby surface water bodies, intrusive maintenance workers, the terrestrial ecosystem and the aquatic ecosystems of the creeks and rivers and potential consumers of impacted aquatic biota within the surface water receptors.

Potentially complete source-pathway-receptor linkages have been identified for the migration of PFAS to impact ecological receptors in the investigation areas and in in adjoining waterways:

- For the Mission River catchment (Andoom HEQ), a potentially complete exposure pathway has been identified for:
    - aquatic receptors in Andoom Creek to be exposed to via PFAS in surface water.
- For the Embley River catchment (Lorim Point, Evans Landing, Weipa Airport and East Weipa HEQ), complete exposure pathways have been identified for:
    - terrestrial receptors (e.g. invertebrates) to be exposed to PFAS in soil and by harvesting; and
    - aquatic receptors in the Embley River to be exposed to PFAS in surface water.

Environmental Values

Based on the available information, it is concluded that there is no adverse impact on the environmental values. This is based on the following:

- Risks to ecological receptors are considered likely to be acceptable

- There is negligible risk to human and ecological health from the consumption of aquatic biota and environmental values relating to aquatic food consumption and aquaculture
- Surface water quality is considered currently suitable for recreational use
- Groundwater from potable abstraction bores is considered currently suitable for drinking water purposes and recreational use
- Groundwater from abstraction bores is considered currently suitable for industrial purposes
- There is a negligible impact on cultural and spiritual values of the water.

Suggested Future Management Approach

The suggested future management approach is for ongoing biannual monitoring of groundwater, surface water and sediment to allow the latest PFAS concentrations to be assessed, to inform changes in trends and to inform current risk to potential receptors.

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by RTA Weipa Pty Ltd (RTAW) to deliver a detailed site investigation (DSI), specifically targeting per- and poly- fluoroalkyl substances (PFAS) in the Weipa and Andoom bauxite mining areas at mining lease 7024, 'the site', on Western Cape York Peninsula in Queensland. The areas under investigation, the 'investigation areas' consist of land used for operational purposes within the Andoom and East Weipa mining leases, the adjoining off-site land areas and the receiving environment that includes the Mission and Embley River catchments. The residential area of Weipa is referred to in this report as Weipa Township. The location of the site and investigation areas is presented in **Figure F1**, **Appendix A**.

1.1 Background

Mining operations in the Weipa and Andoom areas commenced in 1961 and since this time there has been continued expansion of the operations. RTAW's activities comprise a range of mining and associated activities including minerals processing, ore haulage (by road and rail) and product shipping. These activities are supported by a range of infrastructure including power generation, transport facilities (including an airport), water supply and other municipal services. RTAW is responsible for the administration of the town of Weipa through the Weipa Town Authority (WTA). This includes the management and supply of drinking water for the township, which is sourced from groundwater. As part of fire suppression systems and for firefighting training purposes, aqueous film forming foams (AFFFs), potentially containing PFAS, have been stored, used and discharged at, and around, specific buildings and locations in the Weipa and Andoom mining areas.

In October 2017, a soil investigation was conducted at one facility in Andoom (Andoom Heavy Equipment Workshop) and three facilities at Weipa (Lorim Point, Weipa Airport and East Weipa Heavy Equipment Workshop) with PFAS detected in soil at all four locations (reported in Golder, 2018a). Subsequently, a groundwater sampling event was conducted in October and November 2017 to investigate potential PFAS impact to abstraction bores and groundwater monitoring wells across the Andoom and Weipa areas including the Weipa Township. PFAS was detected in groundwater at concentrations that exceeded the adopted human health drinking water guideline values in two monitoring wells. PFAS was not detected above drinking water guideline values in any of the abstraction bores sampled.

Following the soil and groundwater investigations in 2017, a PFAS Assessment Strategy (Golder 2018b) was developed to outline the approach for risk characterisation and assessment. This document was provided to the Department of Environment and Science (DES) in May 2018.

Further groundwater, surface water and sediment sampling and PFAS analysis were conducted in April and June/July 2018, which provided further information on the extent of PFAS impacts in groundwater and surface water across the investigation areas. The results were reported in Golder (2018a).

Following a request from DES, a biota investigation was completed between July and October 2018 that included collection of aquatic biota, sediment and surface water samples from 11 sites representative of the receiving environment including Beening Creek and Mission and Embley Rivers (Golder, 2018c). Out of 83 biota samples analysed, PFAS was detected in four samples, three of which were collected from Beening Creek and one sample from adjacent to Jessica Point. PFAS was not detected in any of the sediment and surface water samples analysed.

On 7 September 2018, DES issued RTAW with a *'Notice to conduct or commission an environmental evaluation'*, (the 'Notice') Reference 101/0008738, CR84931, STAT1304. The Notice identified requirements for a preliminary site investigation (PSI) and DSI to be completed (see **Appendix C**).

The PSI was completed between September and October 2018 (Golder, 2018a), which included reporting the results of the soil, groundwater and surface sampling program conducted between October 2017 and July 2018. Collectively, the 2017/2018 sampling program included the analysis of 51 soil samples, 162 groundwater samples and 34 surface water samples. The results of the investigation indicated PFAS was present in the environmental media in some of the groundwater and surface water samples at locations across the investigation areas at concentrations that exceeded

national ecological screening guidelines (HEPA and DoEE, 2018). PFAS concentrations in some groundwater monitoring wells and surface water samples also exceeded health based guidelines for drinking water and recreational water.

The PSI identified primary, secondary and potential PFAS source areas and developed a preliminary conceptual site model. The primary sources of the PFAS impacts were considered to be the historical use of AFFF products as part of fire suppression systems or firefighting training at the following facilities:

- one location within the Mission River catchment (details regarding the catchment areas are presented in the PSI [Golder, 2018a]):
    - Andoom Heavy Equipment Workshop (Andoom HEQ)
- five locations within the Embley River catchment:
    - Evans Landing (EVL)
    - Railway Workshop (RWW)
    - Lorim Point Industrial Precinct
    - Weipa Airport (WA) and
    - East Weipa Heavy Equipment Workshop (East Weipa HEQ).

The PSI (Golder 2018a) identified eight 'secondary source areas'[2] and six other 'potential source areas' with potential for AFFF release to the environment and relatively lower contaminant concentrations (compared to the primary source areas). The locations of the primary, secondary and potential source areas are shown in **Figure F2**, **Appendix A**.

This document describes the results of the DSI that was completed between November 2018 and April 2019. The investigation has targeted the six primary source areas and one of the secondary source areas (Evans Landing Landfill, located in the Embley River catchment) identified in the PSI. Evans Landing landfill was included at the request of DES following review of the AECOM sampling, analysis and quality plan (AECOM, 2018a).

1.2 Objectives

The overall objectives of this DSI are to understand the nature and extent of the identified PFAS impact and to address Requirement 8 of the DES *Notice to conduct or commission an environmental evaluation*, dated 7 September 2018 (the 'Notice') Reference 101/0008738, CR84931, STAT1304, which is:

> *Submit to the department a Detailed Site Investigation (DSI) report prepared in accordance with Assessment of Site Contamination (ASC) National Environmental Protection Measure (NEPM). Notwithstanding ASC NEPM, the report must:*
>
> *a. Delineate the lateral and vertical extent of contamination at the premises and adjoining impacted land;*
>
> *b. Include an updated CSM; and*
>
> *c. Where environmental harm has been identified, include remediation and management options to address the harm.*

The Notice provided a list of the environmental values from the Environmental Protection (Water) Policy 2009 (EPP Water) that required assessment. These are:

- For slightly disturbed waters – the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators

[2] AECOM understands that the use of the term 'secondary source area' and 'potential source area' refers to areas which are considered to be PFAS source area of lower significance due to less frequent AFFF use/storage and lower PFAS concentrations relative to the primary source areas identified. The PSI regarded these areas of lower priority for investigation.

- For waters that may be used for producing aquatic foods for human consumption – the suitability of the water for producing the foods for human consumption
- For waters that may be used for recreation or aesthetic purposes, the suitability of the water for:
  - Primary recreational use; or
  - Secondary recreational use; or
  - Visual recreational use.
- For waters that may be used for drinking water – the suitability of the water for supply as drinking water
- For waters that may be used for industrial purposes – the suitability of the water for industrial use
- The cultural and spiritual values of the water.

1.3 Scope of Works

The scope of work undertaken to meet the objectives of the investigation is listed below.

- Preparation of a sampling, analysis and quality plan (SAQP) (AECOM, 2018a) that identified the sampling locations, rationale, approach, methodology and proposed quality assurance and quality control measures
- Drilling of 29 soil bores and conversion to groundwater monitoring wells across the six primary source areas
- Advancement of 43 shallow soil bores and sampling across the six primary source areas
- Collection of groundwater samples from 29 new and 44 existing groundwater monitoring wells
- Collection of groundwater samples from 14 abstraction bores
- Collection of 16 co-located surface water and sediment samples and 18 additional surface water samples. The locations targeted the Embley and Mission Rivers and included near shore and offshore sampling, as well as wash bay/pad outlets at the Andoom HEQ and East Weipa HEQ
- Completion of slug tests in up to 10 groundwater monitoring wells to assess hydraulic conductivity of groundwater at each of the six primary source areas
- Laboratory analysis of soil, groundwater, surface water and sediment for PFAS with groundwater and surface water analysed for trace level concentrations. Selected soil samples from each primary source area were analysed for leachable concentrations and for total oxidisable precursor assay (TOPA). Selected groundwater samples from each primary source area were also analysed for TOPA.

Changes made to the scope of work undertaken, relative to the scope proposed in the SAQP are described below, together with the reasons for the changes:

- The target depth of the shallow soil bores was changed from 2.0 m below ground level (mbgl) to 0.5 m. The reason for this change was to mitigate the need for additional permitting requirements to advance the bores to the deeper depth. It was considered that the objective of the investigation (that is, to assess the extent of PFAS contamination) has been met by the completion of the shallow soil bores, together with deeper soil bores converted to groundwater monitoring wells.
- Some of the groundwater monitoring well locations were moved from the locations proposed in the SAQP due to access constraints or permitting issues. The replacement locations were located to meet the objectives of the original monitoring well locations, as far as reasonably practicable.
- One co-located set of surface water and sediment samples was not collected at the Andoom HEQ as the sampling location was not accessible.
- One groundwater monitoring well and one abstraction bore at Weipa Airport were not sampled as the well was dry and the bore not accessible.

- One groundwater monitoring well at Evans Landing has an obstruction present and could not be sampled.
- Two co-located surface water and sediment samples were collected at Andoom HEQ rather than four co-located samples. The change was made following a site walkover, as an area identified for sampling in the SAQP was not a surface water channel.
- Five groundwater monitoring wells and three abstraction bores were not sampled at Lorim Point due to either access requirements, the presence of obstructions in wells or due to the well being destroyed.
- All available abstraction bores were additionally sampled and analysed for PFAS in February 2019 at the request of RTAW to provide the latest groundwater quality in these bores.
- One soil sample from Weipa Airport was planned to be analysed for TOPA and leachate, however due to the non-detection of PFAS in any of the soil samples from Weipa Airport no samples were scheduled for analysis for TOPA and leachate from this area. It was considered that leachability of soils could be informed by the results of leachate analysis on samples with elevated PFAS concentrations from the other primary source areas.
- An additional gauging round was completed in the wet season (February 2019) to provide additional data on groundwater elevations.
- The surface water and sediment sampling locations in November 2018 were resampled in February 2019 following completion of the interim risk assessment (AECOM 2018b). The purpose of the resampling was to provide additional data on seasonal surface water and sediment concentrations.
- Groundwater sampling of five groundwater monitoring wells hydraulically down-gradient of Evans Landing landfill was added to the sampling program (not originally included in the SAQP). This area had been identified in the PSI as a secondary source area (Golder, 2018a), and the sampling was conducted to assess if waste materials in the landfill were a potential source of PFAS contamination of groundwater.
- All additional groundwater, surface water and sediment samples were analysed for PFAS.

2.0 Background to PFAS and Regulatory Framework

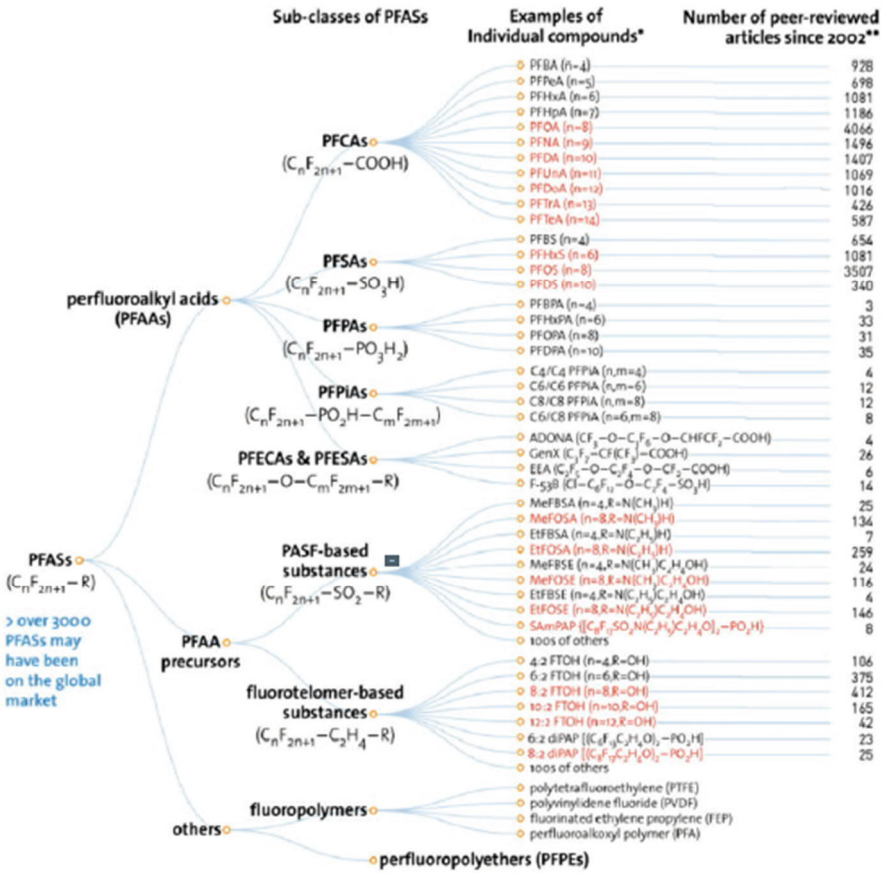
2.1 Background to PFAS

Class B fluorine-containing firefighting foams (firefighting foams) are used for their effectiveness in extinguishing flammable liquid fires and include fluoroprotein, AFFF and film forming fluoroprotein foam. Firefighting foams have been used in Australia since the 1960s and have been mainly stored and used for fire suppression and fire training at military installations and civilian airports, as well as at petroleum refineries, at storage facilities and at chemical manufacturing plants.

Foams are supplied as concentrates, which are then mixed with water and air to form firefighting foam (also described as finished foam). PFAS are a complex family of more than 3,000 man-made fluorinated organic chemicals (Wang et al. 2017) that have been produced since the mid-20th century (see **Plate 1**).

Firefighting foams are estimated to contain between 200 and 600 types of PFAS (PFAS National Environmental Management Plan (NEMP), (HEPA and DoEE, 2018) with both known and unidentified PFAS of differing molecular structures present in varying proportions. Foams were produced to meet firefighting performance specifications rather than formulated to contain a specified mixture of PFAS. PFAS have been produced using two main manufacturing processes, electrochemical fluorination (ECF) and telomerisation. ECF has been used since the 1940s and produces a mixture of even and odd numbered carbon chain lengths of approximately 70% linear and 30% branched substances (Interstate Technology and Regulatory Council (ITRC, 2017). Telomerisation has been used since the 1970s and produces mainly even numbered, straight carbon chain isomers.

Plate 1 PFAS sub classes [3]



[3] Plate sourced *from* (Wang et al., 2017)

Since the late 1990s, environmental researchers have identified PFAS as being environmentally persistent and non-biodegradable, meaning these compounds can travel long distances when released into the environment. They are leachable from soil, mobile in groundwater, and are considered to be bioaccumulative. Research into the potential human health and ecological effects associated with these compounds is currently ongoing, but these chemicals have been identified as emerging environmental chemicals of potential concern (COPC).

The awareness and emphasis on various PFAS are evolving and is at an early stage. The early focus has been on two of the longer fluorinated carbon chains perfluoroalkyl acids (PFAAs), namely perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). There is also increasing focus on perfluorohexane sulfonate (PFHxS), PFOS and PFOA homologues, precursors and transformation compounds. PFHxS has been identified for specific assessment by Food Standards Australia and New Zealand (FSANZ, 2017).

At the time of preparing this report, Australian analytical laboratories, using National Association of Testing Authority (NATA) accredited methods, are currently able to analyse for around 28 PFAS (see **Table 1**). An analytical technique to assess the potential presence of carboxylic and sulfonic acid precursor compounds, which may not be detected using standard analysis, is currently available and termed 'total oxidisable precursor assay' TOPA. The complexity of these potential contaminants including the lack of identification of the compounds in use, their combinations, transformation products and their behaviours contributes uncertainty to the assessment of the risks of the possible health and environmental effects. Development of environmental criteria in Australia to date has focused on PFOS, PFOA and PFHxS.

Table 1 Compounds Analysed in the Extended PFAS Suite

PFAS Group	Compound	Abbreviation	CAS No.
Perfluoroalkyl Sulfonic Acids	Perfluorobutane sulfonic acid	PFBS	375-73-5
	Perfluoropentane sulfonic acid	PFPeS	2706-91-4
	Perfluorohexane sulfonic acid	PFHxS	355-46-4
	Perfluoroheptane sulfonic acid	PFHpS	375-92-8
	Perfluorooctane sulfonic acid	PFOS	1763-23-1
	Perfluorodecane sulfonic acid	PFDS	335-77-3
Perfluoroalkyl Carboxylic Acids	Perfluorobutanoic acid	PFBA	375-22-4
	Perfluoropentanoic acid	PFPeA	2706-90-3
	Perfluorohexanoic acid	PFHxA	307-24-4
	Perfluoroheptanoic acid	PFHpA	375-85-9
	Perfluorooctanoic acid	PFOA	335-67-1
	Perfluorononanoic acid	PFNA	375-95-1
	Perfluorodecanoic acid	PFDA	335-76-2
	Perfluoroundecanoic acid	PFUnDA	2058-94-8
	Perfluorododecanoic acid	PFDoDA	307-55-1
	Perfluorotridecanoic acid	PFTrDA	72629-94-8
	Perfluorotetradecanoic acid	PFTeDA	376-06-7
Perfluoroalkyl Sulfonamides	Perfluorooctane sulphonamide	FOSA	754-94-6
	N-Methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8
	N-Ethyl perfluorooctane sulfonamide	EtFOSA	4151-50-2
	N-Methyl perfluorooctane sulfonamidoethanol	MeFOSE	2448-09-7
	N-Ethyl perfluorooctane sulfonamidoethanol	EtFOSE	1691-99-2
	N-Methyl perfluorooctane sulfonamidoacetic acid	MeFOSAA	2355-31-9
	N-Ethyl perfluorooctane sulfonamidoacetic acid	EtFOSAA	2991-50-6
Fluorotelomer Sulfonic Acids	4:2 Fluorotelomer sulfonic acid	4:2 FTS	757124-72-4
	6:2 Fluorotelomer sulfonic acid	6:2 FTS	27619-97-2
	8:2 Fluorotelomer sulfonic acid	8:2 FTS	39108-34-4
	10:2 Fluorotelomer sulfonic acid	10:2 FTS	120226-60-0

2.2 Overview of Migration Processes Relevant to PFAS

2.2.1 Migration Processes

PFAS are moderately to highly soluble, depending upon the individual PFAS chemical structure. They can be readily dissolved / leached by infiltrating rainwater, groundwater or surface water, and are readily transported away from source areas. The key migration processes for PFAS in water at the investigation areas are considered to include transport in surface water flow during the wet season (overland and in channels), groundwater flow and irrigation of contaminated groundwater.

2.2.2 Unsaturated Zone Transport

Some PFAS can leach from soils and pavements under neutral water conditions. Consequently, the infiltration of water through the soil profile may mobilise some PFAS adsorbed onto and situated within the pore spaces of soil particles (although the rate of mobilisation can be impacted by the soil chemistry and the PFAS chain length and ionic composition). PFAS precursors may also degrade to generate PFOS and PFOA and other shorter chained PFAS in certain physiochemical environments down hydraulic gradient of identified sources.

2.2.2.1 Wastewater and Stormwater Transport

Following release events, finished foam (containing PFAS) can enter stormwater or sewerage systems. Sewage treatment plants are located at RTAW facilities (at Awonga Point and Lorim Point) and Napranum Shire Council. Treated effluent from the first two plants is discharged at the coast adjacent to the facilities, while the latter infiltrates to ground. Open unlined stormwater drains are located across the investigation areas, further detail is provided in **Section 4.2.1**. Standard treatment of wastewater at the site is unlikely to have been effective in removing PFAS.

2.2.2.2 Groundwater Transport

The five general processes used to describe the fate and transport of contaminants such as PFAS in groundwater (Domenico and Schwartz, 1990) are:

1. Advection – transport in groundwater flow;
2. Diffusion – molecular diffusion in an aquifer, independent of flow;
3. Dispersion – hydrodynamic spreading of a contaminant;
4. Adsorption and desorption – retardation of transport; and
5. Degradation – biodegradation of long-chain fluorocarbons.

PFAS investigations have indicated some PFAAs (such as PFOS and PFOA) appear to have little contaminant transport retardation (i.e. adsorption or degradation) based on the extent of the observed contaminant plume and properties of identified PFAS. This is likely the result of the hydrophilic properties of the functional end groups of some PFAS. These and other physiochemical properties will, in some instances, prevent PFAS from adsorbing to most soil particles. PFOS and PFOA are understood to be transported at nearly the same rate as groundwater or surface water (FSANZ, 2017).

As PFAS are transported with water, the concentrations will generally decrease with distance due to the processes of advection, diffusion and dispersion. The environmental fate of the PFAS contaminant mass is expected to be significantly influenced by groundwater movement, extraction and surface water drainage away from a source.

2.2.3 Uncertainties in Assessing PFAS

Of the hundreds of PFAS identified in firefighting foams, toxicological and ecotoxicological data are only available for a few individual compounds (PFOS, PFHxS and PFOA). It should be noted that PFAS are always found as complex mixtures and it is currently unclear if the toxicity of the compounds will act in an additive, synergistic or antagonistic manner. The amount and variety of the different compounds can also be influenced by the nature of the source (i.e. the potential for different active ingredients in the firefighting foam over time), the amount of time the PFAS has been present in the environment, movement and dispersion from the source and the characteristics of the environment.

2.3 Relevant Regulation and Guidance

This DSI has been developed considering the following legislation and guidance.

Environmental Protection (Water) Policy, 2009

The principal legislative basis for water quality management in Queensland is the Environmental Protection (Water) Policy (EPP Water), 2009, which identifies a framework for identifying environmental values of waterways and establishing corresponding water quality objectives to enhance or protect identified environmental values. Environmental values and water quality objectives have not yet been established for the Western Cape York Peninsula. Therefore, the environmental values described in Part A(5) of the Notice have been used to identify the relevant water quality objectives for PFAS under the NEMP (HEPA and DoEE 2018). These are as follows:

- For slightly disturbed waters – the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators;
- For waters that may be used for producing aquatic foods for human consumption – the suitability of the water for producing the foods for human consumption;
- For waters that may be used for recreation or aesthetic purposes, the suitability of the water for:
    - Primary recreational use; or
    - Secondary recreational use; or
    - Visual recreational use.
- For waters that may be used for drinking water – the suitability of the water for supply as drinking water;
- For waters that may be used for industrial purposes – the suitability of the water for industrial use; and
- The cultural and spiritual values of the water.

National Environment Protection (Assessment of Site Contamination [ASC]) Measure (NEPM) 1999, amended April 2013

The ASC NEPM provides guidance on the assessment and remediation of contaminated sites, investigation levels, laboratory analysis procedures, human health and ecological risk assessment methodology, risk communication and community consultation and health and safety issues related to site assessment and remediation. Schedule A of the amended ASC NEPM identifies the tiered process to be followed in the assessment of site contamination, namely: preliminary investigation, detailed investigation and risk assessment. Schedule B of amended ASC NEPM provides detailed guidance for data collection, sample design and reporting. The 2013 amendment to Schedule B of the ASC NEPM includes more detailed and specific guidance on site assessment and human health and ecological risk assessment. The amended ASC NEPM also requires consideration and assessment of ecological risk at all contaminated sites.

The methodology used by AECOM followed the tiered process presented in the ASC NEPM.

National Environmental Management Plan (NEMP), HEPA and DoEE 2018

In January 2018, the PFAS NEMP was issued (HEPA and DoEE, 2018). This document provides a nationally consistent practical risk based framework for the assessment and management of PFAS contamination. The plan provides guidance on the sampling of material potentially contaminated with PFAS, sets out health and ecological guideline values for use in site investigations in Australia and provides guidance on a range of other issues including the reuse of PFAS contaminated materials, treatment and remediation and landfill disposal. The PFAS NEMP is designed to be integrated with the existing national guidelines including the ASC NEPM.

At the time of preparation of this report, ecological screening guideline values for protection of marine waters are in development. Proposed screening guideline values are identified in *CRC CARE*

Technical Report 43. Practitioner guide to risk-based assessment, remediation and management of PFAS site contamination (CRC CARE, 2018), however, these have not yet been adopted.

Notice to conduct or commission an Environmental Evaluation

All works for Requirement 8 of the Notice have been carried out under the supervision of a Suitably Qualified Person as defined in s.564 of the *Environmental Protection Act, 1994*.

While the DSI report has not been prepared as a Contaminated Land Investigation Document, reference has been made to the requirements as presented in *Handbook for Contaminated Land, Module 6: Content requirements for contaminated land investigation documents, certifications and audit reports* (DES, July 2018).

3.0 Investigation Area Setting

3.1 Site Identification and Operations

The investigation areas cover the central portion of Mining Lease (ML) 7024, which is located near the township of Weipa on the western side of the Cape York Peninsula (**Figure F1, Appendix A**). The site is operated by RTAW (formerly Commonwealth Aluminium Corporation) who has been extracting bauxite from the area since the early 1960's. There are two continuous operations within this mining lease, Andoom and East Weipa, located to the north and south of the Mission River, respectively.

The Weipa Township is located to the north of the mining lease and south of the Mission River. The Napranum community, which is governed by Napranum Shire Council is located to south of the mining lease and is adjacent to the Embley River (see **Figure F1, Appendix A**). RTAW are responsible for the administration of the town of Weipa through the WTA which includes the management and supply of drinking water for the township.

RTAW's activities comprise a range of mining and associated activities including minerals processing, ore haulage (by road and rail) and product shipping. These activities are supported by a range of infrastructure including power generation, transport facilities (including an airport), water supply and other municipal services. The general mining process is as follows:

- Clearing of vegetation and removal and stockpiling of top soil
- Mining of bauxite via truck and shovel method
- Transport of mined bauxite by haul truck or rail to either the Lorim Point (East Weipa operations) or Andoom (Andoom operations) beneficiation plant
- Washing and screening of bauxite at the beneficiation plant, transport by rail to the Lorim Point ship loading facility and loading and transport to refineries
- Return of stockpiled top soil to mined areas and rehabilitation of land.

In addition to the above, RTAW own and operate facilities which support the mining operations and communities in Weipa, these include the following (see the PSI (Golder, 2018a) for more information):

- Two diesel power stations located at Lorim Point and Andoom that generate power for the mine and the Weipa and Napranum communities;
- Heavy machinery workshops at Andoom, Lorim Point and East Weipa. These workshops service equipment associated with mining activities such as, dozers, scrapers, loaders, haul trucks and railway locomotives;
- Bulk fuel and oil handling and storage is undertaken by Viva Energy, on behalf of RTAW, at Evans Landing (unloading and storage), Lorim Point (storage) and the Weipa Airport (storage);
- A light industrial precinct at Lorim Point, that includes a light vehicle maintenance workshop, civil workshop, administration offices, chemical laboratories, fire and rescue building (and associated vehicles) and storage facilities;
- The Weipa Airport, which is managed on behalf of RTAW by Aerodrome Management Services;
- Administration offices within the township of Weipa (i.e. environment and community relations); and
- The single persons' quarters (SPQ) accommodation facilities located at Evans Landing and Rocky Point.

RTAW is required to undertake a Receiving Environment Monitoring Program (REMPs) for areas north of Embley River as part of its Environment Authority (EA), EPML00725113. The REMPs are required for areas including: Evans Landing landfill, waters and connected waterways (including groundwater) downstream of infrastructure and extraction areas in East Weipa and Andoom and Awonga Point sewage treatment plant. A second REMP covers Ely (areas in northern Andoom) as part of EA EPML00562613.

The monitoring program includes monthly or quarterly monitoring of surface water and groundwater for a range of non-PFAS COPC.

3.2 Site History

A detailed review of site history is described in the PSI (Golder, 2018a). A brief timeline of activities relevant to the PFAS investigation is presented in **Table 2**. Details on the use of AFFF at the investigation areas are provided in **Section 3.5.1**.

Table 2 Site History Summary

Year	Comment
1960	Bauxite mining commenced at East Weipa.
1961	Evans Landing fuel depot operational.
1960s	Evans Landing beneficiation plant operational.
1972	Mining began at Andoom and servicing of locomotives and wagons commenced at the railway workshop.
1979	Fire and rescue building constructed at Lorim Point, servicing of heavy mobile equipment began at Andoom HEQ.
1980s	Evans Landing landfill developed for disposal of domestic and industrial waste.
1985	Fire suppression systems first installed on heavy mobile equipment.
1991	Heavy mobile equipment servicing commenced at East Weipa HEQ.
1998	Drainage areas installed at Andoom HEQ and East Weipa HEQ.
2004	Evans Landing fuel depot decommissioned.
2005	Fire suppression systems on all heavy mobile equipment became mandatory.

A summary of the historical use of AFFF at the six primary source areas is presented in **Table 3**.

Table 3 Summary of AFFF (potentially containing PFAS) use at the Investigation Areas

Area	Details
Andoom HEQ	The PSI (Golder, 2018a) identified that AFFF potentially containing PFAS was released to the environment at Andoom HEQ during annual servicing of fire suppression systems on heavy mobile equipment during the period 1997 to 2017. It was inferred that approximately 300 L of AFFF may have been released to the environment each year. There were also reports of fire suppression systems being inadvertently discharged at locations across the Andoom mining lease area.
Evans Landing	The PSI (Golder, 2018a) identified limited evidence for firefighting training using AFFF at the bulk fuel depot in the north (ELN) or at the decommissioned bulk fuel depot in the south (ELS). The report identified the potential for a fire training building to be present near the ELN. The PSI considered it likely that training exercises using AFFF occurred in the tank farm areas.
Railway Workshop	The PSI (Golder 2018a) identified that locomotives with fire suppression systems containing AFFF have been serviced at the railway workshop every six months, with AFFF discharged to ground prior to 2015. It was inferred that approximately 50 L of AFFF may have been released to the environment each year between 2000 and 2015.
Lorim Point	The PSI (Golder 2018a) identified that the Lorim Point Fire and Rescue (F&R) building in the Industrial Precinct was the primary location for fire training activities in the area and identified that approximately 100 L of AFFF has been

Area	Details
	released to the environment each year between 2000 to 2017. The number of training exercises was reported to vary from two to six per year with an average of three training events per year using AFFF. It was reported that AFFF has been dispensed in training events from a fire truck containing 200 L of concentrated product, a fire trailer containing 1,000 L of concentrated product and foam extinguishers ranging from 9 kg to 50 kg. Training exercises using AFFF have been undertaken on unpaved ground to the north, west and south of the F&R building. Fire extinguisher training for site personnel involved discharging the extinguishers within training events or to the concrete structure to the north east of the F&R building.
Weipa Airport	The PSI (Golder 2018a) identified that training events at Weipa Airport using AFFF have been undertaken every two years since 2008 (possibly longer). It is inferred that approximately 50 L of AFFF may have been released to the environment each time training occurred. Release of AFFF may have also occurred in this area from activities at the fuel depot located south east of the runway.
East Weipa HEQ	The PSI (Golder 2018a) identified that fire suppression systems have been serviced annually at the East Weipa HEQ workshop, with AFFF potentially containing PFAS discharged to ground prior to 2017 and hosed with water to remove product from the working area. It was inferred that approximately 300 L of AFFF may have been released to the environment each year.

3.3 Layout of the Six Potential Primary Source Areas

Further details on the layout and operations at the six potential primary source areas, which are the focus of this DSI, are described in the following subsections. These areas are predominantly located within ML 7024, however, parts of the Evans Landing, Lorim Point and Weipa Airport source areas are located outside the mining lease on associated subleases.

3.3.1 Andoom Heavy Equipment Workshop

Infrastructure at Andoom HEQ consists of a main workshop used for the servicing of heavy equipment. Offices, break-rooms and storage facilities are located on the eastern side of this building. Surrounding this main building is a bitumen carpark (northeast), laydown yard (east and south), wash bay (south) and tyre lay down (west). The workshop is constructed on concrete; however, the surrounding area is unsealed ground. Current features at Andoom HEQ are shown in **Figure F3, Appendix A**.

The areas to the east, south and west of Andoom HEQ are densely vegetated with most areas being rehabilitated post-mining. More infrastructure associated with the servicing of heavy equipment is located directly to the north followed by the Andoom beneficiation plant. The mouth of the Mission River is situated approximately 6 km to the south of Andoom HEQ.

3.3.2 Evans Landing

Operations at Evans Landing include an active bulk fuel depot in the north and a decommissioned bulk fuel depot in the south. A jetty (and associated buildings) managed by North Queensland Bulk Ports is located at the southern-most edge of the area. A building associated with the State Emergency Service (SES) is situated in the eastern portion of the area, followed by the SPQ buildings and commercial / industrial properties. The Defence Weipa Ares Depot is present further to the east. Directly north and west of the area appears to be vacant land which transitions into the Evans Landing Landfill to the west. A closed tailings stockpile facility is situated approximately 600 m north of the Evans Landing. The Embley River forms the southern boundary of this area. Ground cover in the area largely consists of bare ground, with some grass cover and scattered trees. Site layout and infrastructure are shown on **Figure F4**, **Appendix A**. The layout of the Evans Landing landfill is depicted in **Figure F5, Appendix A**.

3.3.3 Railway Workshop

The railway workshop area is comprised of one main building, which contains offices, break-rooms, storage areas and the main locomotive workshop. To the east of this main building is a carpark, followed by a storage shed and laydown area. A small drainage ditch runs parallel to the southern edge of the buildings, followed by a bitumen walking track and a vegetated area. To the south of the workshop across Florence Hibbard Drive, is the Boral concrete facility. The Lorim Point industrial precinct and civil workshop area are located a further 600m to the south. A laydown area is situated at the western edge of the workshop area followed by vacant land. Several railway tracks run along the workshop's northern edge, running east to west toward the Lorim Point loading facility and the Andoom mining area. A large tailings dam is located further northwest of the workshop. The layout of the area and locations of the infrastructure are shown on **Figure F6, Appendix A**.

3.3.4 Lorim Point Industrial Precinct

The Lorim Point industrial precinct is made up of multiple buildings including the fire and rescue building as shown on **Figure F7**, **Appendix A**. To the east of this area are several stockpiles and the decommissioned calcination plant, and further west are two large fuel storage tanks. The Lorim Point ship loading facility is located to the south of the area, in the Embley River. To the west of the area are more buildings associated with mining operations (procurement shed, offices etc.) which are bordered by dense vegetation. The civil workshop is located to the northwest of the fire and rescue centre. As previously mentioned, the railway workshop is located further north of Lorim Point.

3.3.5 Weipa Airport

The main features at Weipa airport are a runway, running northwest to southeast, a main terminal building located to the south of the runway and a fuel depot, operated by Viva Energy, to the southeast of the terminal building. Weipa Airport is predominantly surrounded by the East Weipa mining operations. Rehabilitated land lies to the south followed by Beening Creek, which discharges into the Embley River in the west. The redundant Weipa Airport landfill is located 400 m west of the airport's terminal. The landfill is a former sand quarry, which was infilled during the 1990s and 2000s. The 3 m deep void was infilled with waste including conveyor belts, tires, cars, batteries, cables, concrete and uncontrolled public waste. Site layout and surrounding infrastructure are shown on **Figure F8**, **Appendix A**.

3.3.6 East Weipa Heavy Equipment Workshop

Infrastructure at East Weipa HEQ is similar to that at Andoom HEQ, with a large main workshop located in the centre of the site, surrounded by a carpark (east), laydown yard (south) and wash bay facilities (west). The workshop is constructed on concrete; however, the surrounding area is bare ground. Active mining operations are present to the north of the workshop, while densely vegetated land is present to the east, south and west. Further south across the Peninsula Development Road is the airport runway (approximately 2 km distant). Trunding Creek is situated approximately 1 km to the north of the workshop. Site layout and surrounding infrastructure are shown on **Figure F9**, **Appendix A**.

3.4 Surrounding Land Use

Land uses in the areas surrounding the site are provided in **Table 4**.

Table 4 Surrounding Land Use

Direction	Land Use
North / northwest	Undeveloped land of the Mission River and Wenlock River catchments. The residential community of Mapoon is located on the northern banks of the Embley River, an estuarine inlet of the Wenlock River 36 km north of the Investigation Area.
South	Embley River and undeveloped land of the Embley River catchment. Development activities have commenced south of the Embley River for bauxite mining as part of the Amrun Project.
East	Royal Australian Air Force (RAAF) Base Scherger is located on the northern side of the Peninsula Development Road, to the east of the Weipa mining area. The Base covers approximately 5,500 ha and has been present since 1998. The facility is identified as a non-operational “bare base”, staffed by limited personnel but with capacity to accommodate up to 1,400 personnel.
West	Albatross Bay and the Gulf of Carpentaria

3.5 Previous PFAS Investigations

A large number of environmental investigations for non-PFAS COPC have been carried out at the site.

3.5.1 Preliminary Site Investigation

A PSI was conducted in 2018 (Golder, 2018a) to assess potential PFAS contamination within and surrounding the Weipa and Andoom mining areas. In addition to the six primary source areas for PFAS at the site (identified in **Section 1.1)**, the PSI identified eight secondary source areas and six other potential source areas (refer to Golder 2018a for more detail). One of the secondary sources was Evans Landing landfill.

The field investigations for the PSI included the following:

- 51 soil samples from Andoom HEQ, East Weipa HEQ, F&R and the Airport were analysed for PFAS. This included analysis of five soil samples for TOPA and leachable testing using with deionised water using the Australian Standard Leaching Procedure (ASLP) on five samples.
- Sampling of 17 groundwater monitoring wells in October/November 2017 and 66 groundwater monitoring wells in June/July 2018 from across the investigation areas, and analysis of groundwater samples for PFAS.
- A total of 24 potable water supply wells and accumulation points were sampled in October and November 2017 respectively. In addition, 21 potable water supply wells and three accumulation points were sampled in April and July 2018, and six wells and one accumulation point were resampled in July 2018 to confirm laboratory results. Samples were analysed for PFAS.
- 24 surface water locations were sampled in April 2018 and ten surface water locations were sampled in July 2018. Samples were tested for PFAS.

Further information on the findings of the desk study and investigation results are discussed below, focussing on the six primary source areas, which were the key areas investigated as part of the DSI.

3.5.1.1 Firefighting Foams

The PSI (Golder, 2018a) reported that on-site procurement records indicated current AFFF included Solberg RF3 and RF6 (both reported as being fluorine-free) and Chubb Aerowater 3% (noted to contain PFOA). No information on historical foam concentrate was identified. A total of 678 L of foam was reported to have been procured by RTAW in 2017. The result of concentrate analysis on two samples of CHUBB 3% and 6% in 2017 were reported in the PSI. In the CHUBB 3% sample, no PFOS, PFHxS or PFOA was detected, however, concentrations of PFBA, PFPeA, PFHxA and PFHpA and 6:2 FtS were detected. In the CHUBB 6% sample, 6:2 FtS was detected at the highest concentration (3 mg/kg) with all other PFAS detected at concentrations below 0.5 mg/kg.

3.5.1.2 Andoom Heavy Equipment Workshop

During the 2017 investigation (reported in the PSI, Golder, 2018), PFAS was detected in four near surface soil samples collected from locations adjacent to the workshop, vehicle wash pad and downstream of the discharge point. No soil sample concentrations exceed the human health and ecological guideline for industrial land use (HEPA and DoEE, 2018).

Four surface water samples were collected from the Andoom area (Andoom Creek, wash tower, washpad and downstream of the washpad). PFAS was detected in all samples with exception of the sample downstream of the washpad (maximum of 0.39 µg/L PFHxS+PFOS in a sample collected in April 2018).

Three abstraction bores (SA091-093) have been monitored on up to four occasions during 2017 and 2018. PFHxS+PFOS concentrations were detected in four out of the eight samples with a maximum concentration of 0.006 µg/L. All concentrations were below the human health guideline for drinking water (HEPA and DoEE, 2018).

Twelve groundwater monitoring wells in area of the Andoom HEQ were sampled during 2017 and all samples recorded detectable concentrations of PFAS. Two groundwater samples recorded PFHxS+PFOS concentrations (AHEQ_MW03 at 0.078 µg/L and AHEQ_MW06 at 0.099 µg/L) that exceeded the human health guideline for drinking water (HEPA and DoEE, 2018).

PFAS was detected in surface water samples from six locations across the greater Andoom mining lease area. None of the concentrations exceeded the human health guideline for recreational water. Three samples recorded PFOS concentrations (maximum of 0.32 µg/L PFHxS+PFOS) that exceeded the adopted aquatic ecosystem guideline (99% protection of freshwater species).

3.5.1.3 Evans Landing

Groundwater from 12 groundwater monitoring wells at ELN was sampled in November 2017 and June 2018. PFAS was detected in nine of the 12 samples. Seven samples from monitoring wells (that are not used for potable purposes) recorded PFHxS+PFOS concentrations that exceeded the human health guideline for drinking water with the maximum concentration detected in ELS_MW18 (0.71 µg/L). This sample also exceeded the human health guideline for recreational water.

PFAS (PFHxS+PFOS) was detected at concentrations of 0.0011 µg/L and 0.0008 µg/L in surface water collected near the jetty and approximately 300 m west of the jetty, respectively. These concentrations were below the human health guideline for recreational water but above the ecological guideline value for protection of freshwater ecosystems (HEPA and DoEE, 2018).

3.5.1.4 Railway Workshop

Groundwater monitoring of four abstraction bores close to the railway workshop on five occasions during 2017 and 2018 did not detect PFAS concentrations at concentrations above the human health guideline for drinking water (HEPA and DoEE, 2018). Groundwater samples from five groundwater monitoring wells (that aren't used for potable purposes) sampled in November 2017 and June 2018 recorded detectable concentrations of PFAS. One sample recorded PFHxS+PFOS concentrations that exceeded the human health guideline for drinking water (RWW_MW01 at 0.278 µ/L).

3.5.1.5 Lorim Point Industrial Precinct

Soil investigations conducted in 2017 and 2018 included analysis of 14 soil samples (reported in the PSI, Golder, 2018). PFAS was detected in all samples, however, concentrations did not exceed the human health guideline for industrial land use (HEPA and DoEE, 2018). Two soil leachate samples recorded concentrations of PFHxS+PFOS with one sample (from FR_TP12) recording 154 µg/L PFHxS+PFOS.

PFAS was detected in groundwater samples from 20 monitoring wells sampled in Lorim Point between November 2017 and June 2018 (reported in the PSI, Golder, 2018) with 13 samples exceeding the human health drinking water guideline (HEPA and DoEE, 2018) . The maximum concentration recorded was 4.1 µg/L in LPI_MW08.

PFAS was detected in two surface water samples in Embley River, one near the ship loading jetty at Lorim Point and one approximately 600 m west. The recorded PFAS concentrations were below the

HEPA and DoEE (2018) human health guideline for recreational water but above the ecological guideline for marine water protection (99% species protection).

Potable water for residential mining accommodation and commercial receptors at Lorim Point and Evans Landing is supplied by a network of seven potable wells connected to accumulation tanks. PFAS was detected in all of the abstraction bores that were monitored during 2017 and 2018 (15 samples from three bores) and the accumulation point at Lorim Point. All recorded PFAS concentrations were below the human health guideline for drinking water (maximum PFHxS+PFOS was 0.048 µg/L).

3.5.1.6 Weipa Airport

A soil investigation identified detectable PFAS concentrations in two of 24 soil samples from 15 sampling locations. None of the recorded soil concentrations exceed the adopted human health or ecological guidelines for industrial/commercial landuse (HEPA and DoEE, 2018). One of the soil leachate samples recorded a PFHxS+PFOS concentration of 0.181 µg/L.

Abstraction bore SA026 was monitored on four occasions between October 2017 and July 2018. PFAS was detected in all samples, however the PFHxS+PFOS concentrations (maximum of 0.048 µg/L) were not detected above the human health guideline for drinking water (HEPA and DoEE, 2018). Groundwater from seven groundwater monitoring wells to the southwest of the runway recorded detectable concentrations of PFAS. One sample from a well near the fuel depot (AFD-MW36) recorded a PFHxS+PFOS concentration (0.136 µg/L) that exceeded the human health guideline for drinking water.

3.5.1.7 East Weipa Heavy Equipment Workshop

PFAS was detected in five near-surface soil samples collected from one location adjacent to EWHEQ, two locations adjacent to the vehicle wash pad and two locations downstream of the discharge point. With one exception all concentrations were all below the human health and ecological guideline for industrial / commercial land use (HEPA and DoEE, 2018). One location, (ID not known) recorded 1.08 µg/L PFHxS+PFOS. One near-surface soil leachate sample (EWHEQ_SS16 0.1) recorded a PFHxS+PFOS concentration of 0.11 µg/L. Surface water samples from the East Weipa HEQ wash bay discharge outlet and a location downstream recorded detectable concentrations of PFAS. Concentrations in both samples were below the human health recreational water screening level and above the ecological guideline level for 99% freshwater species protection (HEPA and DoEE, 2018).

Abstraction bore SA027 was monitored on four occasions between October 2017 and July 2018. PFAS was detected in all four samples, however the human health guideline level for drinking water (HEPA and DoEE, 2017) was not exceeded.

Groundwater from six groundwater monitoring wells located to the south and southwest of EWHEQ were monitored in 2017 and 2018 and recorded detectable concentrations of PFAS. Samples from the two wells to the southwest of the area (EWHEQ_MW02 and EWHEQ_MW05) recorded PFHxS+PFOS concentrations that exceeded the human health guideline for drinking water (HEPA and DoEE, 2018). The maximum concentration was 0.242 µg/L in EWHEQ_MW05.

3.5.1.8 Other Areas

A total of 35 groundwater samples were collected from nine abstraction bores from Weipa Township between October 2017 and July 2018 (reported in the PSI, Golder, 2018a). PFAS was detected in ten of these samples (representing five separate bores) with no exceedances of the human health guideline level for drinking water.

Six surface water samples were collected in April 2018 from the Northern East Weipa Mine area reported PFAS concentrations below human health guidelines for recreational water (HEPA and DoEE, 2018). Five surface water samples from four river locations within the East Weipa mine area recorded concentrations of PFAS below the LOR.

3.5.2 DES Groundwater Sampling

In November 2017, DES collected eight samples from abstraction bores used by the Napranum Community located south of the Weipa investigation area (DES, 2018). With one exception, PFAS was not detected in the water samples. PFOS was detected at 0.011 µg/L in a sample described as

'raw' water in the report (DES, 2018). This concentration was below the human health drinking water guideline level (HEPA and DoEE, 2018).

3.5.3 Biota Investigation

An assessment of aquatic biota was undertaken by Golder (2018c), as requested by DES in May 2018, and with input into the methodology from DES and the Department of Agriculture. The objectives of the sampling and analyses were to undertake a Tier 1 human health risk (HHRA) and ecological risk assessment (ERA), and compare the co-located sediment PFAS concentrations from background sites to PFAS concentrations in sediment at potentially impacted downstream areas. Fishing within the large mangrove, tidal creek and mudflat systems in Albatross Bay is considered an important subsistence, economic and recreational activity in the Weipa region. Human consumption of potential PFAS impacted aquatic biota represents a potentially complete exposure pathway.

Aquatic biota, sediment and surface samples were collected from 11 sites across the investigation area at Weipa. The biota samples included aquatic species commonly consumed in the area from a range of ecological groups with varied mobility from pelagic fish to sessile invertebrates.

The biota sampling investigation area targeted the receiving areas from four identified primary PFAS source areas (Andoom Heavy Equipment Workshop, Weipa Airport, Lorim Point and East Weipa Heavy Equipment Workshop) as follows:

- Andoom Creek as the receiving environment associated with the Andoom Heavy Equipment Workshop;
- The tidal creeks, foreshore, mangrove and mudflats of the Mission River including Trundling Creek prior to it entering Albatross Bay as the potential receiving environment associated with the East Weipa Heavy Equipment Workshop and the north Weipa Peninsular;
- The lower Embley River in the Weipa Channel downstream of the confluence between the Hey and Embley Rivers and Beening Creek as the potential receiving environment for the Weipa Airport and Weipa Fire and Rescue; and
- Background/reference sites including upstream locations, or locations where biota are unlikely to be exposed to PFAS from identified PFAS source areas.

A total of 257 fish (32 species), 136 crustaceans (5 species), 48 molluscs (3 species) and 32 gastropods (1 species) were collected during the survey conducted from 16 to 25 July 2018. Of the 473 individuals across all taxa caught, 193 were retained for laboratory analysis. The biota samples were processed to extract the edible portions of the whole-body samples provided to the laboratory.

The aquatic biota species that were retained for analysis were as follows

- *Finfish:* Northwest black bream, Yellowtail grunter, Milkfish, Blue threadfin, Hawaiin gian herring, Goldenspotted rockcod, Blackspotted rockcod, Longtain catfish, Common silverbiddy, Diamonscale mullet, Striped snapper, Moses snapper, Sea mullet, Blue catfish, Fourline stiped grunter, Spotted javelinfish, Blue swimmer crab, Milk shark, Striped cat.
- *Crustaceans:* Mud crab, Endeavour prawn, Brown tiger prawn
- *Bivalve and Gastropods:* Mud whelk, Pacific oyster, Pipi, Blood cockle

3.5.4 Interim Risk Assessment (AECOM, 2018b)

An interim risk assessment on potential risks associated with PFAS in the Weipa and Andoom mining areas on Western Cape York Peninsula was conducted in November 2018 (AECOM, 2018b). The overall objective of the work was to understand the nature and extent of the identified PFAS impact and to address Requirement 6 of the DES *Notice to conduct or commission an environmental evaluation*, dated 7 September 2018, which is:

> *"Using the findings and results of the PSI and Biota Assessment completed in requirements 3 and 4 respectively, by 30 November 2018, prepare and submit to the department an Interim Risk Assessment that assesses the risk to environmental values and details interim management measures to protect the relevant environmental values."*

The interim risk assessment was based on the review and incorporation of findings from historical reports prepared by Golder (2018a,c). Potential risks to environmental values associated with human and ecological health were assessed by comparison of measured PFAS concentrations in soil, water (ground- and surface), sediment and biota against Australian guidelines. A CSM was developed that indicated where linkages between sources of PFAS and receptors (both human and ecological) were likely to be complete (and therefore present a potential risk) or incomplete (in which case risks were considered to be negligible).

The interim risk assessment identified exceedance of human health and ecological guideline values in groundwater samples from monitoring wells at some locations in the investigation areas, such as the Andoom HEQ, Evans Landing, Railway Workshop, Lorim Point, Weipa Airport and East Weipa HEQ. No exceedances of drinking water guidelines for groundwater currently used for potable purposes were identified.

An assessment of the aquatic biota, sediment and surface water samples was completed. The biota samples included species commonly consumed across the investigation area, and included a range of ecological groups from pelagic fish to sessile invertebrates. The reported PFAS concentrations in all biota samples analysed were at least an order of magnitude below the adopted guidelines. The reported PFAS concentrations for all co-located surface water and sediment samples analysed were below the laboratory limit of reporting. Based on the available information, the Tier 1 assessment of biota, sediment and surface water concluded that there is negligible risk to human and ecological health from the consumption of aquatic biota and environmental values relating to aquatic food consumption and aquaculture.

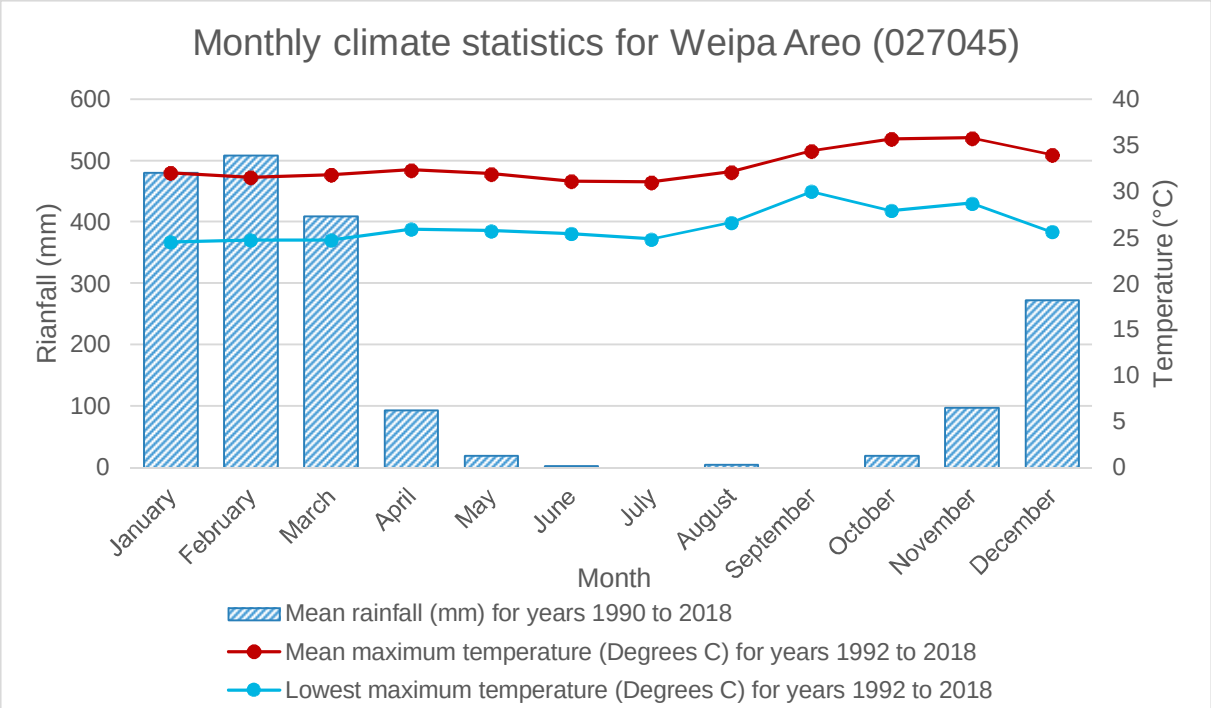
4.0 Environmental Setting

4.1 Climate

Weipa is within the Australian Monsoon Zone which has a tropical climate, characteristic of distinct wet and dry seasons. The wet season (summer) is relatively short, lasting approximately from December to March, and occurs due to changes in the direction of the prevailing trade winds, which change from southeast to the northwest. More than 95% of the region's rainfall occurs between November and April (see **Chart 1**). Wet season inundation of flood plains resulting from overtopping of the main channel banks is a seasonal characteristic of the area. Mean annual rainfall at Weipa (Bureau of Meteorology, 2018 for Weipa Aerodome station 027045) is 1,911 mm (1990 to 2018).

Cyclones regularly affect the Weipa area between December and April. From the available records there is on average at least one tropical cyclone per year in the Gulf of Carpentaria, with the number ranging from zero to five in any one year (RTAW, 2018).

Chart 1 Weipa Climate Data



4.2 Site Topography and Hydrology

The Andoom and Weipa areas are characterised by flat coastal plains, with elevations typically reaching 30 m above sea level. Topography dips gently to the west to a low scarp and coastal plain. Elevations increase toward the Great Dividing Range located approximately 120 km to the east.

Two catchments divide the area in an east-west direction, the Mission River catchment (2,697 km^2) to the north and the Embley River catchment (1,925 km^2) to the south. A series of sub-catchments including creeks, tributaries and swamps have been identified by RTAW and are shown on **Figure F1, Appendix A**. The Mission and Embley Rivers are tidally influenced and discharge west into Albatross Bay (Gulf of Carpentaria).

Creeks in the Ely mining area (north of Andoom) drain into the Mission, Pine and Wenlock rivers and are flanked by mangrove swamps along the estuarine margins. Watercourses on the Weipa Peninsula drain into the Mission or Embley Rivers, while those in the Andoom region drain into the Mission and Pine Rivers and are marked by mangrove swamps along estuarine margins. Creeks in the area are predominantly ephemeral, with flow only occurring during wet season. Some streams are

connected to the underlying shallow aquifer, and as such are more likely to flow perennially with water sourced from this shallow aquifer during dry season (RTAW, 2018). Groundwater fed springs and swamps can be observed throughout the Weipa area (i.e. Willum Swamp and Thwitharran Spring).

Previous investigations into surface flow across the mining lease found that surface runoff is very low, which is typical of the low-lying topography and the high infiltration rates of the soils and lateritic strata present across the area (RTAW, 2018). This means that streamflow does not respond quickly to incident runoff until after the catchment is "wetted up" and there is no "first flush" response to rainfall at the start of the wet season (RTAW, 2018). Typically, wet season rainfall begins in November, however it is generally not until January, after soil moisture stores are at capacity, that streams show appreciable flow (RTAW, 2018). Flows increase until March or April as a response to wet season rainfall and then decrease once rainfall ceases (RTAW, 2018).

4.2.1 Surface Water Resources

Albatross Bay acts as an important resource to the Weipa community and RTAW mining operations. Recreational and commercial fishing occurs in several areas along the Mission and Embley Rivers as well as at Beening Creek. During wet season, runoff flows into depressions creating ephemeral creeks and swamps that are used by residents for swimming.

4.2.2 Drainage

Drainage in the greater Weipa area is dominantly comprised of open, unlined channels, which largely run along the edges of roadways and drain into streams and rivers.

Surface runoff from the railway workshop is collected in drains and channelled into an oil/water separator before being discharged into a drainage ditch to the north of the building (Golder, 2018a). Anecdotal evidence collected by in the PSI (Golder, 2018a) indicated that upgrades had occurred on the drainage system to incorporate the oil/water separator, however no timeframes were provided as to when this work occurred. Prior to these upgrades, surface water flowed straight into the drainage ditch.

The topography at Lorim Point grades slightly toward the Embley River in the south. Open, unlined drainage ditches run along most roads in this area, with flow assumed to discharge into the Embley River. Similar drainage systems were noted at both the airport and at Evans Landing. Topography at Evans Landing dips slightly to the south, with open channels directing surface water down gradient toward the Embley River. At the Airport site, channels are present at both ends of the runway. It is anticipated that surface runoff flows along these channels and discharges to Beening Creek in the southeast.

Spoon drains were installed at East Weipa HEQ between 1996 and 1997 to collect surface runoff from the workshop floor. Water is collected in a sediment trap located to the west of the building, before passing through a humiceptor where it is discharged to a sediment pond near the vehicle wash bay. Water from this pond is discharged into the open area to the southwest of the southwest of the wash bay, while sediment is collected periodically and disposed of at the bioremediation pad at Lorim Point (Golder, 2018).

4.3 Geology and Soils

Review of regional geology maps indicate that the Weipa area lies within the Holocene to Late Cretaceous Karumba Basin, which is superimposed upon the Mesozoic Carpentaria Basin (Geoscience Australia, 2019). The regional stratigraphy is summarised in **Table 5**.

Table 5 Stratigraphy of the Weipa area

Basin	Age	Group	Formation	Units / description	Hydrogeological Properties
Karumba Basin	Miocene - Pliocene		Wyaaba Beds	Clayey quartzose sand and sandstone	Partial aquifer
	Oligocene		Bulimba Formation	Aurukun Surface	-
	Paleogene			Uningan Sandy Clay	-
				Beening Sand	-
				Trunding Clay	Semi confining
				Napranum Sand	Aquifer
Carpentaria Basin	Early to Late Cretaceous	Rolling Downs Group	Normanton Formation	Sandstone, siltstone, minor mudstone and limestone.	Partial aquifer
			Allaru Mudstone	Medium grained glauconitic sandstone grading up to interbedded sandstone and siltstone.	Aquitard
			Toolebuc Formation	Carbonaceous to calcareous silt and claystone with minor sandstone.	
			Wallumbilla Formation	Argillicious with some fine to coarse grained quartz sandstone.	
	Early Cretaceous		Gilbert River Formation	Medium to coarse-grained, clayey quartzose sandstone and pebbly sandstone); minor conglomerate, siltstone, mudstone.	Aquifer
	Late Jurassic		Garraway Sandstone	Clayey micaceous quartzose sandstone, granule and pebble conglomerate.	Aquifer

The Paleogene Bulimba Formation (formerly Weipa Beds) is the basal unit of the Karumba Basin (Geoscience Australia, 2019). It unconformably overlies the Normanton Formation (formerly Awonga Beds) of the Rolling Downs Group (Carpentaria Basin) (Geoscience Australia, 2019) and marks the first of three depositional cycles which formed the Karumba Basin.

Previous studies have divided the Bulimba Formation into the following units (Halcrow, 2012):

- Aurukun Surface – mappable planation surface, acts as marker for the top of the Bulimba Formation
- Uningan Sandy Clay – strongly weathered, nodular ironstone and bauxite common
- Beening Sand – fining upward succession, distribution and thickness of this unit is variable. Lithologically similar to the Napranum Sand and in some areas difficult to differentiate
- Trunding Clay – fining upward succession, compositionally defined by 70 – 90 % kaolinite, 5 – 20 % quartz and 1 – 3 % muscovite (and other minor constituents), discontinuous to the east
- Napranum Sand – fine to coarse grained poorly sorted quartz rich sand, compositionally varies from a clean sand to ~50 % clay.

At the Andoom mining area, the Normanton Formation is reported to directly underlie the bauxite, suggesting the absence of the Bulimba Formation (Taylor et. al., 2009).

The uppermost units of the Karumba Basin comprise Miocene to Pliocene unconsolidated sediments of the Wyaaba Beds, which predominantly consist of clayey quartzose sand and sandstone (Geoscience Australia, 2019). Along coastal flats, associated with the Embley River, Mission River, Pine River and Andoom Creek, this material is characterised by alluvial mud, silt and sand. These sediments were deposited during the Wyaaba cycle which commenced in the late Oligocene (Grimes, 1979).

Review of bore logs from previous intrusive investigations indicate subsurface conditions across the investigation area are relatively consistent (Golder, 2013; Halcrow, 2012; Otek, 2010a; Otek, 2010b). The profile generally includes, gravelly sand with minor clay from surface to a maximum of 5.2 mbgl followed by a discontinuous clay to clayey sand varying in thickness from 0 – 5 m, underlain by sand to the maximum depth of investigation (11 – 13 mbgl). At the Andoom mining area the underlying sand unit is largely absent, and is instead replaced by silty clays (Halcrow, 2012).

Regionally, the predominant soil type present within the investigation area as defined by the Australian Soil Classification (ASC) are kandosols (Queensland Globe, 2019). This soil type is characterised by loamy mottled yellow and red sandy earths with a prominent ironstone nodule horizon at depth (Queensland Globe, 2019; Biggs and Philip, 1995). Soils present along drainage lines and river banks is classified as a hydrosol, which is characterised by saturation of the soil profile for at least 2 – 3 months of the year.

The probability of acid sulfate soil presence across the investigation area is reported as extremely low (1 – 5%) (ASRIS, 2019).

4.4 Hydrogeology

The Normanton Formation and the Gilbert River Formation are recognised as the deep regional aquifers underlying the Andoom and Weipa areas (Golder, 2018a). These rocks formed as part of the greater Carpentaria Basin which in turn forms the northernmost portion of the Great Artesian Basin (GAB). This deep regional aquifer is overlain by younger rocks of the Karumba Basin with the Napranum Sand of the Bulimba Formation generally representing a high yielding shallow aquifer (Golder, 2018a). Definitions of hydrogeological units in the Weipa area are detailed in **Table 6**.

The shallow aquifer (Napranum Sand) acts as an important groundwater resource for the Weipa Peninsula (Golder, 2018a). The aquifer's potentiometric surface generally follows surface topography and groundwater flow is predominantly east to west, although along the coast of the Weipa Peninsula flow is radially outward towards the surrounding bays (Golder, 2018a). Groundwater in the shallow aquifer is relatively fresh due to high annual rainfall and recharge.

In most areas recharge to the shallow aquifer occurs via rainfall infiltration. This is promoted by the porous nature of the overlying bauxite and ironstone; however, it is noted in some studies that groundwater recharge in disturbed areas, where kaolin and bauxite are mined out, may result in changes to recharge behaviour. It is anticipated that groundwater discharge occurs along surface water courses as well as along the coastal edges of the peninsula.

Previous regional hydrochemical studies of groundwater suggest a vertical connection between the Karumba Basin and the underlying Normanton Formation aquifer, however; vertical connectivity between these units has not been assessed on a local scale.

There have been various studies focused on determining aquifer properties of the Napranum Sand (Bulimba Formation) and Trunding Clay, a summary of these findings is presented in **Table 6**. This information indicates high variability within the shallow aquifer. The Trunding Clay acts as a semi-confining layer in some areas, indicated by a rebound in standing water level from water strike observed in bore logs (Otek, 2010a; Golder, 2013).

Table 6 Aquifer properties

Unit	Hydraulic Conductivity	Transmissivity	Source	Comments
Napranum Sand (Bulimba Formation)	0.83 – 2.08 m/day	25 m^2/day	Golder, 2008	Calculated assuming an aquifer thickness of 12 to 30 m
	183 – 259 m/day	-	Coffey and Hollingworth, 1971	Average values from tests on three production bores.
	-	1,708 – 5,628 m^2/day	Wilson Consulting (Pty) Ltd, 2016	Average values calculated off pump test completed on five supply bores across the Weipa Peninsula
Bulimba Formation (undifferentiated)	140 – 335 m/day	-	Coffey and Hollingsworth, 1971 (in Smerdon et al., 2012)	Based on pump tests completed on production bores.
	205 m/day	-	Chapman, 1963 (in Smerdon et al., 2012)	Long term pump tests on three observation bores.
Trunding Clay	0.3 m/day	-	Golder, 2008	

4.4.1 Groundwater Resources

Drinking water for the township of Weipa and surrounding areas is sourced from abstraction bores and supplied by either the WTA or RTAW.

RTAW supplies drinking water to the following areas:

- Weipa airport
- Andoom mining area
- Weipa mining area.

The WTA supplies drinking water to the following areas:

- Weipa township, including all residential properties and public services (i.e. schools, recreation areas, hospital);

- Evans Landing; and
- Lorim Point.

Registered groundwater wells within the mining lease and Weipa Township were reviewed by Golder (2018a). This review found a total of 291 shallow aquifer (Napranum Sand) and 13 deep artesian groundwater bores. Of these, the available information indicated that 31 are used for potable supply, while the remaining bores are used for:

- monitoring of RTAW mining operations (80);
- abstraction for use in mining operations (53); and
- irrigation (1).

The majority of water extracted is used for mineral processing and dust suppression in the mining areas. Some unregistered groundwater bores are known to be in operation on the Weipa Peninsula for non-potable uses such as garden watering and filling swimming pools (Golder, 2018a).

4.5 Environmentally Sensitive Areas

A search was undertaken of environmentally sensitive areas located within the Andoom and Weipa areas using information available in the Queensland Globe (2019). The results of this search are presented in **Table 7**.

Table 7 Environmentally Sensitive Areas Located on and Adjacent to the Site

Feature name	Relevant legislation	Description
Fish habitat – Management area A	*Queensland Fisheries Act, 1994; Fisheries Regulation, 2008*	A declared fish habitat area is an area protected against physical disturbance from coastal development, while still allowing legal fishing. The specific objective of this area includes the *'management of fish habitats in Pine River Bay; protection of popular local Indigenous, recreational and commercial fishing and fishing charters'* (DES, 2012).
Matters of State Environmental Significance (MSES) – regulated vegetation (essential habitat)	*Nature Conservation Act, 1992*	Areas prescribed as having 'endangered wildlife' or 'vulnerable wildlife'.
MSES – regulated vegetation	*Vegetation Management Act, 1999*	Defined as areas that are 'endangered' or 'of concern' regional ecosystems.
MSES – wildlife habitat (threatened and special least concern animal)	*Nature Conservation Act, 1992*	For preservation of the saltwater crocodile (Crocodylus porosus) – essential habitat.
MSES – regulated vegetation	*Environmental Protection Regulation, 2008; Environmental Protection (water) Policy, 2009 (schedule2)*	Vegetation within 100 m of a defined wetland.
Protected plants trigger area – high risk	*Nature Conservation Act, 1992; Nature Conservation (wildlife management) Regulation, 2006*	Endangered, vulnerable and / or near threatened vegetation identified.

5.0 Fieldwork- DSI

5.1 Overview

Fieldwork was completed in accordance with the Sampling Analysis and Quality Plan (SAQP) dated 1 November 2018 (AECOM 2018a). The fieldwork was completed between November 2018 and February 2019. Details of tasks completed are shown in **Table 8**.

Table 8 Summary of Fieldwork

Activity	Location	Dates
Service clearance and acquisition of dig permits (conducted by RTAW)	Andoom HEQ, Evans Landing, Weipa Airport, Railway Workshop, Lorim Point, East Weipa HEQ	5 – 17 November 2018
Drilling of 29 soil bores and installation of groundwater monitoring wells across the six primary source areas. Soil sampling and well development	Andoom HEQ, Evans Landing, Weipa Airport, Railway Workshop, Lorim Point, East Weipa HEQ	5 – 17 November 2018
Advancement of 43 shallow soil sampling (to 0.5 mbgl)	Andoom HEQ, Evans Landing, Weipa Airport, Railway Workshop, Lorim Point, East Weipa HEQ	13 – 20 November 2018
Groundwater monitoring event	Andoom HEQ, Evans Landing, Evans Landing Landfill, Weipa Airport, Railway Workshop, Lorim Point, East Weipa HEQ	18 – 27 November 2018 19 – 22 February 2019
Surface water and sediment sampling	Embley River (on and offshore)	21 November 2018 23 February 2019
	Beening Creek	21 and 27 November 2018 19 – 21 February 2019
	East Weipa HEQ	21 and 23 November 2018 19 February 2019
	Andoom HEQ	23 November 2018 19 – 21 February 2019
Positional surveying	Andoom HEQ, Evans Landing, Weipa Airport, Railway Workshop, Lorim Point, East Weipa HEQ	21 February 2019
Rising / falling head tests	Andoom HEQ, Evans Landing, Weipa Airport, Railway Workshop, Lorim Point, East Weipa HEQ	20 – 22 February 2019

5.2 Sampling Rationale

An overview of the rationale for sampling locations is presented in **Table 9**. The sampling locations are shown on **Figure F3** to **Figure F9, Appendix A**. The coordinates of sampling positions are shown in **Table T1**, **Appendix B**. Photographs taken during the fieldworks are shown in **Appendix D**.

Table 9 Sampling Rationale

Source Area	Sample location	Sample Medium	Rationale
Andoom Heavy Equipment Workshop	AHEQ_SS01 to AHEQ_SS07	Soil	Shallow soil bores advanced in the operational area immediately north and south of the workshop where AFFF potentially containing PFAS was discharged to ground. The sampling was conducted to assess the extent of PFAS in soils within this potential primary source area.
	AHEQ_MW07, AHEQ_MW08, AHEQ_MW09, AHEQ_MW10, AHEQ_MW11	Soil and groundwater	To assess the potential lateral extent of PFAS in groundwater hydraulically down gradient of the AHEQ to the south, southeast and southwest of the workshop area.
	AHEQ_MW03, AHEQ_MW04, AHEQ_MW05, AHEQ_MW06, ASB_MW08, ASB_MW10, ASB_MW21, ASB_MW23	Groundwater	To assess the lateral extent of PFAS in groundwater at this potential source area, at locations hydraulically up, down and cross-gradient.
	PR/AND/WS, PR/AND/DOS	Water and sediment	To assess PFAS in surface water and sediment in the wash pad and downstream of the washpad.
Evans Landing	ELN_SS01 to ELN_SS02, ELS_SS01 to ELN_SS05	Soil	Shallow soil bores advanced to assess the lateral and vertical extent of PFAS in soils within the potential source area.
	ELN_MW10, ELN_MW09, ELS_MW29, ELS_MW28	Soil and groundwater	To assess the potential lateral extent of PFAS in groundwater hydraulically up, down and cross gradient (north and east) of the potential source area to characterise soil and groundwater.
	ELN_MW04, ELN_MW06, ELN_MW07, ELN_MW30, ELS_MW18, ELS_MW19, ELS_MW21, ELS_MW25, ELL_MW32	Groundwater	To assess the potential lateral extent of PFAS in groundwater hydraulically up, down and cross gradient of the Evans Landing potential source area.
	EMB/EV/NSA, EMB/EV/NSB, EMB/EV/NSC, EMB/EV/OSA, EMB/EV/OSB, EMB/EV/OSC	Surface water and sediment (nearshore only)	Three nearshore surface water and sediment samples and three offshore surface water samples taken at both high and low tide to characterise PFAS concentrations in the potential receiving environment and allow assessment of the risk to human health and ecological receptors.

Source Area	Sample location	Sample Medium	Rationale
Railway Workshop	RWW_SS01 to RWW_SS04	Soil	Shallow soil bores advanced to assess the lateral and vertical extent of PFAS in soils in the potential source area, to the south and west of the rail workshop.
	RWW_MW06 to RWW_MW08	Soil and groundwater	To assess the lateral extent of PFAS in soil and groundwater to the north, southwest and southeast of the potential source area.
	RWW_MW01 to RWW_MW05	Groundwater	To assess the lateral extent of PFAS in groundwater around the rail workshop.
Lorim Point	LPI_SS01 to LPI_SS08	Soil	Shallow soil bores advanced to assess the lateral and vertical extent of PFAS in soils in the area with known PFAS impacts.
	LPI_MW32	Soil and groundwater	To assess PFAS in groundwater upgradient and to the north of the potential source area.
	LPI_MW25 – LPI_MW27	Soil and groundwater	Located within the potential source area to assess the lateral and vertical extent of PFAS in soil and groundwater.
	LPI_MW28 – LPI_MW31	Soil and groundwater	Located to the south, west and southwest of the potential source area to assess the lateral extent of PFAS.
	LPI_MW07, LPI_MW19, LPI_MW21, LPW_MW33	Groundwater	To assess the lateral extent of PFAS in groundwater downgradient of the potential source area.
	SA012, SA014, SA015	Groundwater (potable well)	To assess potential human health risks from PFAS in groundwater extracted for use and to provide information on lateral extent of PFAS in groundwater.
	EMB/LP/NSA, EMB/LP/NSB, EMB/LP/NSC, EMB/LP/OSA, EMB/LP/OSB, EMB/LP/OSC	Surface water and sediment (nearshore only)	Three nearshore surface water and sediment samples and three offshore surface water samples taken at both high and low tide to assess PFAS concentrations in the potential receiving environment and allow assessment of the risk to human health and ecological receptors.
Weipa Airport	AP SS01 – AP SS08	Soil	To assess shallow soil quality for PFAS at either end of the runway, at potential locations where AFFF was discharged as part of historical fire training activities.

Source Area	Sample location	Sample Medium	Rationale
	ALF_MW06, ALF_MW07, AFD_MW37	Soil and groundwater	To assess the lateral extent of PFAS in soil and groundwater downgradient of the potential source area.
	AP_MW01, AP_MW02	Soil and groundwater	To assess the lateral extent of PFAS in soil and groundwater hydraulically cross and downgradient at either end of the runway.
	ALF_MW01, ALF_MW02, ALF_MW03, ALF_MW04, AFD_MW22, AFD_MW36	Groundwater	To assess the lateral extent of PFAS in groundwater downgradient of the potential source area.
	SA005, SA026	Groundwater (potable well)	To assess potential human health risks from PFAS in groundwater extracted for use and to provide information on lateral extent of contamination.
	SW/BEN/UPS, SW/BEN/MID, SW/BEN/DOS	Surface water and sediment	Sampling of surface water and sediment to understand potential PFAS impacts in the receiving environment and allow assessment of the risk to human health and ecological receptors.
East Weipa Heavy Equipment Workshop	EWHEQ_SS01 to EWHEQ_SS08	Soil	Shallow soil bores advanced to assess lateral and vertical extent of PFAS in soils immediately south and southwest of the workshop in areas where AFFF containing PFAS was discharged to ground.
	EWHEQ_MW06 to EWHEQ_MW09	Soil and groundwater	To assess the lateral extent of PFAS in soil and groundwater around the primary source area.
	EWHEQ_MW01, EWHEQ_MW02, EWHEQ_MW04, EWHEQ_MW-05	Groundwater	To assess the lateral extent of PFAS in groundwater around the primary source area
	SA027, RN78251, RN109710	Groundwater (potable well)	To assess potential human health risks from PFAS in groundwater extracted for use and to provide information on lateral extent of contamination.
	PR/EWM/WP, PR/EWM/WP/DOS, PR/EWM/02	Surface water and sediment	Sampling of surface water and sediment at the wash bay discharge outlet and downstream locations to understand potential PFAS impacts in the receiving environment and allow assessment of the risk to human health and ecological receptors.
Evans Landing Landfill	MB5, MB7, MB9, MB13, MB18	Groundwater	To assess the potential for a source of PFAS to be present in the landfill.

5.3 Methodology

Due to the ubiquity of PFAS used in a variety of everyday products and the potential for cross contamination during sampling activities, the recommended mitigation practices identified in the NEMP (2018) and Western Australia's Department of Environmental Regulation (2017) were implemented during the sampling program as stipulated in the SAQP (AECOM, 2018a).

5.3.1 Soil Investigation

Sampling methodologies and details relating to laboratory analysis of samples are described in the SAQP (AECOM, 2018a). The soil investigation methodology is described in **Table 10**.

Table 10 Soil Investigation Methodology

Activity/Item	Details
Service location	AECOM obtained on-site utility plans and Dial-Before-You-Dig service before the start of the works. RTAW completed service location and completed dig permits prior to commencement of the intrusive works. Deeper soil bore locations (for conversion to monitoring wells) were advanced by non-destructive drilling (NDD) methods to 2.0 mbgl to confirm the absence / presence of underground utilities. NDD involved the use of high-pressure water and a vacuum to remove soil while minimising potential damage to any existing utilities.
Drilling method(s)	Soil bores (for conversion to groundwater monitoring wells) were advanced with a Geoprobe drilling rig using solid stem augers to the target depth. Shallow soil bores were advanced using a hand auger to refusal.
Soil bores and target depth	Soil bores (for conversion to groundwater monitoring wells) were advanced to a maximum depth of 12 mbgl. Shallow soil bores were advanced using a hand auger to a maximum depth of 0.2 mbgl, where refusal was encountered in all bores.
Soil logging	Soil logging was in accordance with the unified soil classification system (USCS) and AS1726-2016. The soil profile(s) encountered are provided in bore logs in **Appendix E**.
Soil sampling	During NDD, soil samples were collected at each soil location using a hand auger. Samples were collected near the surface (0.1 mbgl) and at approximately 0.5 m intervals thereafter to a maximum of 2.0 mbgl. During drilling, samples were obtained at varying depths dependent on lithological change and water strike. To reduce the likelihood of cross contamination, soil samples were collected using new nitrile gloves and placed into laboratory prepared PFAS sample containers. All samples were filled to the top and securely sealed. AECOM selected soil samples for laboratory analysis based on the following: • Soil at or near ground surface where shallow soil may have been impacted by contaminated surface water or direct exposure to fire-fighting foam. • Soil within the saturated zones, where PFAS present in groundwater may have adsorbed onto soil particles. A selection of soil samples were also analysed for TOPA and/or soil leachate. The field quality assurance / quality control (QA/QC) samples comprised intra-laboratory duplicate samples, inter-laboratory duplicate samples and rinsate blanks.
Soil sample preservation	During collection in the field, soil samples were placed in eskies kept cool with ice bricks before being transferred to a clean fridge before being packaged into eskies for air transport to the laboratory. Samples were submitted with chain-of-custody documentation to an accredited laboratory.

Activity/Item	Details
Decontamination procedures	The decontamination procedures were performed before initial use of re-useable equipment and after each subsequent use. All reusable sampling equipment was decontaminated between each sample by scrubbing in a solution of Liquinox and potable water before being rinsed in PFAS free distilled water. For each day of sampling, following decontamination procedures, a rinsate blank was completed by running laboratory prepared rinsate water over the reusable sampling equipment for collection directly into laboratory prepared sampling containers for analysis. At each sample location, a new set of disposable nitrile gloves was used to directly collect soil samples from the re-useable sampling equipment for placement into the laboratory prepared sampling containers.
Disposal of waste	Soil generated was disposed of in a plastic lined, bunded pit, located at the bioremediation pad at Lorim Point. Waste disposal was managed by RTAW.

5.3.2 Groundwater Investigation

The groundwater investigation methodology is described in **Table 11**.

Table 11 Groundwater Investigation Methodology

Activity	Detail
Monitoring well installation	Monitoring well construction nominally comprised of a 50 mm diameter uPVC screen and plain casing with screw fittings installed in an approximately 150 mm diameter bore. Wells were installed to an approximate depth of 12 mbgl. Screen length varied between wells dependent on water strike. Screened sections were installed in a gravel filter pack to 0.5 m above the top of the screen and isolated with a 1 m thick bentonite seal. Each well was fitted with either a stick-up monument or flush mounted gatic dependant on location and secured into position with concrete. A water tight enviro-cap was installed on the top of each well casing to prevent accidental blockage of the well.
Well development	Wells were developed following installation via either airlift or using a high-density polyethylene (HDPE) PFAS free hand bailer. The wells were purged until the extracted water was 'clearing' and field parameters were stabilised. Monitoring well construction details can be found in **Table T1**.
Well gauging	Monitoring wells were gauged using an oil/water interface probe. The results of groundwater level gauging are presented in **Table T2**. The fieldsheets and calibration certificates are provided in **Appendix F**.
Field Parameters	Groundwater physicochemical properties were measured in the field prior to sample collection using a calibrated YSI water quality meter. Groundwater pH, temperature, electrical conductivity, redox potential and dissolved oxygen concentrations were measured. Groundwater physicochemical parameters are presented in **Table T3**. Water quality meter calibration certificates are contained in **Appendix F**.
Groundwater sampling	The groundwater sampling procedure is described in detail in the SAQP (AECOM, 2018a). Groundwater samples were collected from each monitoring well using a low flow bladder pump in accordance with Australian Standard AS5667.11 (1998) and the AECOM Standard Operating Procedure (SOP). Samples were obtained following stabilisation of field parameters and standing water level. Where groundwater was sampled from potable supply bores, the bores were left to run until a minimum of 10 L had been purged to allow fresh

Activity	Detail
	samples to be collected. Samples were collected straight into lab supplied bottles and water quality parameters were taken via grab sample. The field QA/QC samples comprised intra-laboratory duplicate samples, inter-laboratory duplicate samples, rinsate blanks and trip blanks.
Sample preservation	During collection in the field, samples were placed into the appropriate laboratory-supplied containers and placed in an esky, which was kept cool with ice bricks. Samples were transferred to a clean fridge before being delivered to the lab via air freight. Samples were submitted with chain of custody documentation to an accredited laboratory.
Decontamination procedures	The oil/water interface probe and bladder pump were decontaminated by scrubbing in a solution of Liquinox and potable water before rinsing with PFAS free distilled water between each groundwater well. A rinsate sample was collected from either the interface probe or bladder pump each day of sampling. Dedicated bladders, tubing and nitrile gloves were used for each well sampled.
Disposal of waste	Purged groundwater was disposed of in a plastic lined, bunded pit, located at the bioremediation pad at Lorim Point.
Surveying	Surveying of newly installed groundwater wells was completed by a Denada Surveys. The surveying report is presented in **Appendix G**.
Hydrogeological testing	Rising head tests were completed on at least two of the newly installed groundwater wells at each source area. Data loggers were deployed in each well and approximately 1 L of water was removed using a disposable bailer. The results are presented in **Appendix H**.

5.3.3 Surface Water Investigation

The surface water sampling methodology is summarised in **Table 12**.

Table 12 Surface Water Investigation Methodology

Activity	Details
Surface water sampling	Surface water sampling was conducted in accordance with Australian Standard for Water Quality Sampling (AS 5567:1998). Samples were collected from six locations (three onshore and three offshore) along the Embley River on both incoming and outgoing tides, during both wet and dry seasons. The offshore samples were collected from a boat at the same time as the near shore samples. At each location a new and laboratory supplied bottle was attached to a telescopic sampling pole and lowered into the surface water. The sample bottle was filled to the top to ensure no headspace and the cap was immediately applied. Samples were taken at three locations along Beening Creek (see **Figure F8**) during dry season and three locations during wet season, two samples were taken from a drainage channel near the Andoom HEQ and two samples were taken from a drainage channel (wash bay discharge outlet) near the East Weipa HEQ. In each of these instances' samples were collected straight into laboratory supplied bottles. Samples were collected from immediately below the water surface to minimise disturbance of the water column and to minimise suspension of sediment in the samples.
Collection of field physicochemical data	A calibrated YSI Quatro Pro Plus was used to measure physiochemical parameters by placing the probes in a sample of the surface water collected in a container. General observations of the surface water quality and flow were recorded. The fieldsheets are presented in **Appendix F**.
Sample preservation	During collection in the field, samples were placed into the appropriate laboratory-supplied containers and placed in an esky, which was kept cool with ice bricks. Samples were transferred to a clean fridge before being packaged up and sent to the lab via air freight. Samples were submitted with chain-of-custody documentation to an accredited laboratory.
Decontamination	The sampling pole was decontaminated by scrubbing in a solution of Liquinox and potable water before rinsing with PFAS free distilled water between sampling locations. Rinsate blank samples were collected from the sampling pole during sampling.

5.3.4 Sediment Investigation

The sediment sampling methodology is summarised in **Table 13**.

Table 13 Surface Water Investigation Methodology

Activity	Details
Sediment sampling	Samples were collected using a gloved hand placing samples directly into laboratory sample jars. At each location the sample jar was filled to the top to ensure no headspace and the cap was immediately applied.
Sample preservation	Samples were placed into the appropriate laboratory-supplied containers Samples were stored in a clean fridge before being packaged up and sent to the lab via air freight. Samples were submitted with chain-of-custody documentation to an accredited laboratory.
Decontamination	A new pair of disposable nitrile gloves was used to collect each sediment sample to avoid the potential for cross contamination.

5.4 Laboratory Analysis and Quality Assurance / Quality Control

5.4.1 Soil

A total of 115 soil samples were submitted to ALS for analysis for PFAS (suite of 28 compounds identified in **Table 1**). Of these soil samples five were selected for TOPA analysis and five were selected for Australian standard leaching procedure (ASLP) for PFAS using deionised water. The soil samples with the highest PFAS concentrations from the primary source areas were selected for additional analysis.

5.4.2 Groundwater

A total of 95 groundwater samples were submitted to the laboratory for analysis for PFAS at trace level concentrations (super trace) for the suite of 28 compounds identified in **Table 1**. This included 23 samples from abstraction bores, two samples from registered bores and 70 samples from groundwater monitoring wells. Six of these samples were submitted for TOPA analysis, with the sample from each potential source area selected for analysis.

5.4.3 Surface Water

A total of 56 surface water samples and 31 sediment samples collected were analysed for PFAS. All surface water samples were analysed for trace level concentrations (super trace) for the suite of 28 compounds identified in **Table 1**.

5.4.4 Summary

A summary of samples analysed from different areas of the investigation area is shown in **Table 14**.

Table 14 Summary of Laboratory Analyses

Area	Number of samples analysed for PFAS			
	Soil	Groundwater	Surface Water	Sediment
AHEQ	21 (3 TOPA, 1 ASLP)	15 (1 TOPA)	4	3
Evans Landing	20 (1 TOPA, 1 ASLP)	13 (1 TOPA)	24	6
Rail Workshop	10 (1 TOPA, 1 ASLP)	12 (1 TOPA)	0	0
Lorim Point	27 (1 TOPA, 1 ASLP)	16 (1 TOPA)	24	6
Weipa Airport	18	13 (1 TOPA)	5	4
EWHEQ	19 (1 TOPA, 1 ASLP)	12 (1 TOPA)	4	6
Weipa Township	0	9	0	0
Evans Landing Landfill	0	5	0	0

5.4.5 Quality Assurance / Quality Control Sampling

Quality assurance / quality control (QAQC) samples analysed are summarised in **Table 15**.

Table 15 Number of QAQC samples analysed

Item	Duplicate	Triplicate	Rinsate
Soil	7	8	28
Groundwater	13	13	
Surface Water	6	6	
Sediment	2	2	

The QA/QC results and data validation summary are presented in **Appendix I**.

5.4.6 Data Quality Objectives and Analytical Data Validation

The *National Environment Protection (Assessment of Site Contamination) Measure (*as amended 2013) (ASC NEPM) Schedule B 2 Guideline on-Site Characterisation specifies that the nature and quality of the data produced in an investigation will be determined by the data quality objectives (DQO). As referenced by the ASC NEPM, the DQO process is detailed in the United States Environmental Protection Agency (US EPA, 2006) *Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4 : EPA/240/B-06/001),* February 2006. The DQOs were specified within the SAQP and are presented in **Appendix I**.

AECOM has undertaken a review of the laboratory analytical results for quality control purposes; the results of the data validation process are presented in **Appendix I** and the laboratory quality control reports are included in **Appendix J**. In summary, while some non-conformances have been identified, these are considered of minor importance and it is concluded that the dataset presented in this report is suitable for use in the assessment.

6.0 Assessment Criteria

The adopted investigation levels (IL) were used as an initial screen to assess the risk (if any) to human health and the environment. Tier 1 Human Health and Ecological Screening Guidelines for PFAS have been sourced from NEMP (2018) and are shown in **Table 16**. Selected ILs have been based on an understanding of environmentally sensitive areas, human interaction and ecological significance within the investigation area and receiving environment.

Table 16 Adopted investigation levels for PFAS

Media	Description	PFAS	Human Health	Ecological
Soil	Industrial / commercial	PFOS	-	0.140 mg/kg [A]
		PFOA	50 mg/kg	-
		Sum of PFHxS and PFOS	20 mg/kg	-
Groundwater	Drinking water	PFOS	-	-
		PFOA	0.56 µg/L	-
		Sum of PFHxS and PFOS	0.07 µg/L	-
Surface water	Aquatic ecosystem	PFOS	-	0.00023 µg/L or LOR[B]
		PFOA	-	19 µg/L[B]
	Recreational water	PFOS	-	-
		PFOA	5.6 µg/L	-
		Sum of PFHxS and PFOS	0.7 µg/L	-

Notes:
A - NEMP (HEPA and DoEE, 2018) interim ecological value for indirect exposure
B- NEMP (HEPA and DoEE, 2018) 99% species protection – high conservation value systems – fresh and interim marine. The LOR is adopted to provide a detect threshold where the analytical laboratory cannot achieve the required reporting level.

7.0 Results

This section presents the results of the investigation conducted between November 2018 and February 2019. An interpretation of the new and historical (2017/2018) datasets is presented in **Section 8.0**.

7.1 Soil Conditions

The bore logs for the 29 new bores drilled in November 2018 are shown in **Appendix E**. All bores were drilled to between 12.0 and 15.0 mbgl. The general geological succession for each source area is summarised in **Table 17** below.

Table 17 Summary of Soil Conditions in the Bore Logs

Source Area	Description
AHEQ	Silty clay, clayey gravel or silty sand in the upper two metres, underlain by silty, sandy or gravelly clay. There is a transition to clay between 9.0 and 11.5 mbgl to 15.0 mbgl, the maximum depth of drilling.
Evans Landing	Variable layers of clayey sand, sandy clay, clay, silty gravel, sandy gravel, gravelly clay to 11.0 mbgl, the maximum depth of drilling.
Rail Workshop	Gravelly clay / clayey gravel up to 5.2 mbgl, underlain by silty and sandy clay to between 8.2 to least 12.0 mbgl. There is a transition to clay below approximately 8.2 mbgl.
Lorim Point	Sandy clayey gravel, gravelly clay, sandy silt or sand are present to approximately 3 to 7 mbgl, which is underlain by silty clay, sandy clay or clay with some sand lenses to at least 12.0 mbgl.
Weipa Airport	Variable layers of silty clay, clayey gravel, sandy silt, sand, sandy clay or clayey sand are present to at least 12.0 mbgl, the maximum depth of drilling.

There was no visual or olfactory indication of contamination in the soil samples during the drilling.

7.2 Hydrogeology

7.2.1 Groundwater Elevations and Groundwater Flow Direction

Groundwater monitoring wells sampled during this investigation were gauged on two occasions, representative of the end of the dry season (in November 2018) and at the end of the wet season (in February 2019). The standing water levels (in metres below top of casing [mbtoc]) measured during the gauging and groundwater elevations (in metres above Australian Height Datum [mAHD]) are presented in **Table T2**, **Appendix B** and summarised in **Table 18** below.

Table 18 Summary of Standing Water Levels and Groundwater Elevations in November 2018 and February 2019

Area	SWL / GW Elevation (November 2018- dry season)	SWL / Elevation (February 2019)	Average head difference between November 2018 and February 2019
Andoom HEQ	9.65 to 13.87 mbtoc 0.80 to 3.31 mAHD	1.51 to 6.97 mbtoc 8.57 and 10.04 mAHD	7.6 m
Evans Landing	4.46 to 9.43 mbtoc 0.14 to 0.81 mAHD	3.33 to 5.46 mbtoc 1.33 and 2.26 mAHD	2.1 m
Rail Workshop	5.64 to 8.96 mbtoc 0.89 to 1.25 mAHD	Not recorded	Not recorded

Area	SWL / GW Elevation (November 2018- dry season)	SWL / Elevation (February 2019)	Average head difference between November 2018 and February 2019
Lorim Point	5.03 to 8.61 mbtoc 0.48 to 1.59 mAHD	3.43 and 7.47 mbtoc 1.24 and 4.97 mAHD	2.6 m
Weipa Airport	8.40 to 10.87 mbtoc 4.384 to 9.323 mAHD	5.27 to 7.77 mbtoc 6.469 to 12.172 mAHD	2.9 m
East Weipa HEQ	6.733 to 9.457 mbtoc 11.368 to 12.521 mAHD	1.203 to 4.340 mbtoc 16.590 to 18.886 mAHD	5.5 m

Inferred groundwater contour maps for Andoom and Weipa areas in November 2018 (dry season) and February 2019 (wet season) are presented in **Figure F10** A and B and **Figure F11** A and B in **Appendix A**, respectively.

A summary of the inferred groundwater flow directions at each of the sources areas is shown in **Table 19**. The groundwater flow direction does not alter during the dry and wet season, although this could not be confirmed at the Railway Workshop as the gauging data were not available for evaluation.

Table 19 Summary of Groundwater Flow Direction at each Primary Source Area in November 2018 and February 2019

Area	Inferred Groundwater Flow Direction	
	November 2018	February 2019
Andoom HEQ	Northeast to southwest	Northeast to southwest
Evans Landing	North to south towards the Embley River	North to south towards the Embley River.
Railway Workshop	North to south	No data
Lorim Point	Northeast to southwest towards the Embley River	Northeast to southwest towards the Embley River
Weipa Airport	Northeast to southwest towards the Embley River	Northeast to southwest towards the Embley River
East Weipa HEQ	Northeast to southwest towards the Embley River	Northeast to southwest towards the Embley River

7.2.2 Hydraulic Conductivity

Slug tests were conducted in 10 groundwater monitoring wells including:

- Andoom HEQ: AHEQ_MW08, AHEQ_MW11
- Airport: ALF_MW07
- Evans Landing: ELN_MW10, ELS_MW28
- Lorim Point: LPI_MW26, LPI_MW31
- East Weipa HEQ: EWHEQ_MW07, EWHEQ_MW08
- Railway Workshop: RWW_MW06

Out of these ten tests, the responses in six wells were too fast to be recorded on the data loggers (less than 5 seconds). Summary results and estimated hydraulic conductivities for the four other wells are shown in **Table 23.** The results indicated the mean hydraulic conductivity in the four wells where data could be analysed to be between 1.0 and 18 m/day. Hydraulic conductivities in the other wells (where data could not be analysed) is likely to be greater than 18 m/day. Previous reports (Coffey and Hollingsworth, 1971) have indicated the hydraulic conductivity to be approximately 200 m/day. The

difference in the range of hydraulic conductivities estimated reflects the geological conditions at the site.

Table 20 Summary of Slug Test Results

Well	SWL (mbgl)	Screened Zone (mbgl)		Hydraulic Conductivity (K) (m/d)						Mean K-Value	
		Top	Bottom	Test 1		Test 2		Test 3		Early Time	Late Time
				Early Time	Late Time	Early Time	Late Time	Early Time	Late Time		
AHEQ-MW11	2.65	9	15	2	NA	2	NA	3	NA	2.33	NA
LPI-MW26	4.91	6	12	13	NA	14	NA	13	1	13.33	1.00
LPI-MW31	3.93	5	9	6	NA	8	NA	8	NA	7.33	NA
RWW-MW06	2.94	4	9	6	14	7	22	NA	NA	6.50	18.00

7.2.3 Groundwater Flow Velocity

Based on the estimated hydraulic conductivity of 200 m /day (Coffey and Hollingsworth, 1971, pump test data), the average hydraulic gradient measured, and assuming an effective porosity of 30% to represent sand [(Driscoll, 1986), the estimated groundwater flow velocity (using Darcy's Equation) for different investigation areas are as follows:

- Railway Workshop: 9.8 m/day
- Lorim Point: 26.0 m/day
- East Weipa HEQ: 0.7 m/day
- Evans Landing: 18.2 m/day
- Weipa Airport: 3.1 m/day

7.2.4 Water Quality Parameters

Table T3, **Appendix B** presents the field water quality parameter results for groundwater collected during the groundwater monitoring events. The raw data were recorded on the fieldsheets presented in **Appendix F**. A summary of the water quality results is presented in **Table 21**.

Table 21 Summary of Groundwater Quality Parameter Results

	Units	AHEQ	EVL	RWW	LP	WA	EWHEQ	EVL landfill
pH	-	4.3-6.4	3.9-6.1	3.7-5.6	4.0-6.0	3.7-5.9	3.4-5.0	4.7-6.0
Temp	^{o}C	29.3-34.4	29.7-31.7	29.4-31.2	29.5-32.9	30-32.2	29.4-30.4	28.3-31.3
DO	mg/L	0.2-7.2	0.1-4.1	0.5-2.1	0.1-6.8	2.5-6.9	0.5-6.1	0.2-4.1
ORP	mV	-2.5-251	16.6-362	272-385	78.5-232	105-388	216-285	182-287
EC	µS/cm	94.4-595	34-2059	68.3-249	63.4-214	19-123	20.1-36	54-195
TDS	mg/L	61.4-387	22-1338	44.4-162	41.2-139	12.4-80	13.1-23.4	35-127

Overall the field parameter results show a similar range across all locations. The groundwater is generally acidic to slightly acidic, poorly to well oxygenated, slightly oxidising to reducing and fresh. Groundwater in some of the bores adjacent to the estuarine environment at Evans Landing was brackish.

7.2.5 Groundwater Field Observations

There was no visual or olfactory indication of contamination in the wells during the groundwater monitoring.

7.3 Surface Water Quality Parameters

Table 22 below summarises the surface water parameter results. The results are shown in **Table T4**, **Appendix B**.

Table 22 Summary of Surface Water Quality Parameter Results

	Units	Embley River (n=38)	Beening Creek (n=3)	Andoom HEQ (n=2)	East Weipa HEQ (n=2)
pH	-	6.3-8.4	6.2-7.8	6.5-7.3	6.1-6.2
Temp	ºC	28.0-33.3	28.1-29.4	27.0-29.1	29.2-34.8
DO	mg/L	3.0-7.5	1.4-6.2	0.8-5.3	0.7-4.2
ORP	mV	135-396	239-338	233-242	172-189
EC	µS/cm	156-67,605	32-3,870	72.2-167	283-335
TDS	mg/L	101-43,943	21-2,516	46.9-108.5	184-218

The results show the surface water is generally near neutral, moderately to poorly oxygenated, reducing and fresh (in the inland creeks and channels) and fresh to saline (in the rivers).

7.4 PFAS Analytical Results

7.4.1 Soil

7.4.1.1 Andoom HEQ

The soil analytical results are presented in **Table T5** and graphically for PFHxS+PFOS concentrations on **Figure F12**. The laboratory analytical reports are presented in **Appendix J**. Of the 21 soil samples analysed, PFAS was detected in 13 samples. A summary is presented in **Table 23**. There were no exceedances of the human health guideline levels for industrial landuse in the soil samples analysed. One soil sample exceeded the PFOS ecological guideline level for industrial landuse. This was the sample from AHEQ_SS04 at 0.0-0.1 mbgl (0.62 mg/kg PFOS) located approximately 50 m south of eastern portion of the workshop.

The maximum sum of PFAS concentration (based on 28 PFAS analysed) reported was 1.26 mg/kg in the near surface sample from AHEQ_SS04 at 0.0-0.1 mbgl. A deeper sample (at 0.1-0.2 mbgl) from this bore recorded a concentration of 0.582 mg/kg for sum of PFAS. All other results for sum of PFAS concentrations were below 0.242 mg/kg.

Table 23 Summary of PFAS Analytical Results in Soil Samples from Andoom HEQ

Compound	No. of samples analysed	No. of samples >LOR*	Maximum concentration (mg/kg)	No. of samples exceeding human health IL	No. of samples exceeding of ecological IL
PFHxS+PFOS	21	13	1.14	0	No guideline
PFOS	21	13	0.618	No guideline	1 (AHEQ_SS04)
PFOA	21	11	0.016	0	No guideline
Sum PFAS	21	13	1.26	No guideline	No guideline

Note: *LOR is limit of reporting and is 0.0002 mg/kg for PFHxS+PFOS, PFOS and PFOA.

7.4.1.2 Evans Landing

The soil analytical results are presented in **Table T5, Appendix B** and graphically for PFHxS+PFOS concentrations on **Figure F13, Appendix A**. PFAS was detected above the limit of reporting (LOR) in

nine of the 20 soil samples. A summary is presented in **Table 24**. There were no exceedances of the HEPA and DoEE (2018) human health or ecological guideline levels for industrial landuse in the soil samples. The maximum sum of PFAS concentration reported was 0.004 mg/kg in the near surface sample from ELN_MW10 at a depth of 0.4 to 0.5 mbgl.

Table 24 Summary of PFAS Analytical Results in Soil Samples from Evans Landing

Compound	No. of samples analysed	No. of samples >LOR	Maximum concentration (mg/kg)	No. of samples exceeding human health IL	No. of samples exceeding of ecological IL
PFHxS+PFOS	20	9	0.0041	0	No guideline
PFOS	20	9	0.0041	No guideline	0
PFOA	20	0	0.0002	0	No guideline
Sum PFAS	20	9	0.0041	No guideline	No guideline

7.4.1.3 Railway Workshop

The soil analytical results are presented in **Table T5, Appendix B** and graphically for PFHxS+PFOS concentrations on **Figure F14, Appendix A**. PFAS was detected above the LOR in nine of the 20 soil samples. A summary is presented in **Table 25**. There were no exceedances of the HEPA and DoEE (2018) human health or ecological guideline levels for industrial landuse in the soil samples. All concentrations were close to, or below, the LOR. The maximum sum of PFAS concentration reported was 0.0007 mg/kg in the near surface samples from RWW_SS02 and RWW_SS04.

Table 25 Summary of PFAS Analytical Results in Soil Samples from Railway Workshop

Compound	No. of samples analysed	No. of samples >LOR	Maximum concentration (mg/kg)	No. of samples exceeding human health IL	No. of samples exceeding of ecological IL
PFHxS+PFOS	10	4	0.0007	0	No guideline
PFOS	10	4	0.0007	No guideline	0
PFOA	10	0	<LOR	0	No guideline
Sum PFAS	10	4	0.0007	No guideline	No guideline

7.4.1.4 Lorim Point

The soil analytical results are presented in **Table T5, Appendix B** and graphically for PFHxS+PFOS concentrations on **Figure F15 Appendix A**. PFAS was detected above the LOR in 18 of the 27 soil samples. A summary is presented in **Table 26**. There were no exceedances of the HEPA and DoEE (2018) human health guideline levels for industrial landuse in the soil samples analysed. There were two exceedances of the ecological guideline level for PFOS for industrial landuse in two samples from LP_SS07 at 0.0-0.1 mbgl (0.29 mg/kg) and 0.1-0.2 mbgl (0.26 mg/kg). The maximum sum of PFAS concentration reported was 0.353 mg/kg in the sample from LP_SS07 at 0.0-0.1 mbgl. Soil bore LP_SS07 is located in the area where historical firefighting training using AFFF may have occurred.

Table 26 Summary of PFAS Analytical Results in Soil Samples from Lorim Point

Compound	No of samples analysed	No. of samples >LOR	Maximum concentration (mg/kg)	No. of samples exceeding human health IL	No. of samples exceeding of ecological IL
PFHxS+PFOS	27	18	0.31	0	No guideline
PFOS	27	17	0.288	No guideline	2 (LP_SS07 0.1/0.2)
PFOA	27	12	0.0043	0	No guideline
Sum PFAS	27	18	0.353	No guideline	No guideline

7.4.1.5 Weipa Airport

The soil analytical results are presented in **Table T5, Appendix B** and on **Figure F16, Appendix A**. PFAS was not detected in any of the 18 soil samples analysed from the soil bores advanced in this area.

7.4.1.6 East Weipa HEQ

The soil analytical results are presented in **Table T5, Appendix B** and graphically for PFHxS+PFOS concentrations on **Figure F17, Appendix A**. PFAS was detected above the LOR in 15 of the 19 soil samples. A summary is presented in **Table 26**. There were no exceedances of the HEPA and DoEE (2018) human health guideline levels for industrial landuse in the soil samples. The ecological guideline level for industrial landuse for PFOS was exceeded in the two samples from EWHEQ_SS01 at 0.1-0.2 mbgl (0.18 mg/kg) and EWHEQ_SS02 at 0.1-0.2 mbgl (0.45 mg/kg). The maximum sum of PFAS concentration reported was 0.622 mg/kg in the sample from EWHEQ_SS02 at 0.1-0.2 mbgl. These soil bores were collected from an open area approximately 20 m and 50 m south of the workshop.

Table 27 Summary of PFAS Analytical Results in Soil Samples from East Weipa HEQ

Compound	No of samples analysed	Number of samples >LOR	Maximum concentration (mg/kg)	No. of samples exceeding human health IL	No. of samples exceeding of ecological IL
PFHxS+PFOS	19	15	0.47	0	No guideline
PFOS	19	15	0.449	No guideline	2 (EWHEQ_SS01/02)
PFOA	19	11	0.0174	0	No guideline
Sum PFAS	19	15	0.622	No guideline	No guideline

7.4.1.7 PFAS TOPA and Leachate

The PFAS TOPA results for soil samples are presented in **Table T6, Appendix B**. A summary of the soil sample results comparing PFAS and TOPA results for soil samples is presented in **Table 28**. The samples were fully oxidised during the analytical process.

Table 28 Summary of PFAS and TOPA Analytical Results in Soil Samples

Sample	Units	Sum of 28 PFAS (standard analysis)	Sum of 28 PFAS (TOPA)	Sum of TOP C4-C14 Carboxylates and C4-C8 Sulfonates	% of Sum of 28 TOPA to 28 PFAS standard analysis
AHEQ_SS04 0.0-0.1	mg/kg	1.26	0.918	0.918	-27%
ELN_MW10 0.4-0.5	mg/kg	0.0041	0.0069	0.0069	+68%
RWW_SS02 0.1-0.2	mg/kg	0.0007	0.001	0.001	+43%
LP_SS07 0.1-0.2	mg/kg	0.289	0.365	0.352	+26%
EWHEQ_SS02 0.0-0.1	mg/kg	0.622	0.673	0.668	+8%

The results show that the sum of 28 PFAS (TOPA) in four of the samples are between 8% and 68% larger than the sum of 28 PFAS (standard analysis). The other soil sample from AHEQ SS04 showed the sum of 28 PFAS (TOPA) was approximately 27% lower than the sum of 28 PFAS (standard analysis).

These results indicate that there is the potential for precursors to be present in the samples where an increase in PFAS concentration has been detected in TOPA results compared to standard analysis. The difference in concentration also suggests that the environmental oxidation process is slow and that the rate of transformation is likely to remain slow provided the environmental conditions remain the same.

These five soil samples were also analysed for leachate concentrations using the TOPA analytical method. The results are presented in **Table T7, Appendix B** and summarised in **Table 29**.

Table 29 Summary of TOPA and Leachate Analytical Results in Soil Samples

Sample	Sum of 28 PFAS (TOPA) (mg/kg)	Soil Analysis: Sum of TOP C4-C14 Carboxylates and C4-C8 Sulfonates (mg/kg)	Leachable Concentrations Sum of TOP C4-C14 Carboxylates and C4-C8 Sulfonates (µg/L)
AHEQ_SS04 0.0-0.1	0.918	0.918	54.0
ELN_MW10 0.4-0.5	0.0069	0.0069	0.1
RWW_SS02 0.1-0.2	0.001	0.001	0.02
LP_SS07 0.1-0.2	0.365	0.352	9.25
EWHEQ_SS02 0.0-0.1	0.673	0.668	25.8

The results provide a line of evidence that PFAS in the surface soils is readily leachable, however it is noted that the results may be affected by the TOPA methodology which fully oxidises the samples. No leachate analysis was conducted to measure PFAS by standard analysis. The soil sample with highest PFAS concentration (AHEQ_SS04 0.0-0.1) detected during the investigation leaching 54 µg/L of sum of TOP C4-C14 carboxylates and C4-C8 sulfonates.

7.4.2 Groundwater

The groundwater analytical results for samples collected from monitoring wells and abstraction bores are presented in **Table T8, Appendix B** with a summary of the results and exceedances of the adopted investigation levels (ILs) presented in **Table 30** below. Further discussion of the results is provided in the subsections below. All of groundwater samples that exceeded the adopted human health ILs were from monitoring wells that are not used for potable purposes. There were no exceedances of adopted human health ILs in groundwater samples from abstraction bores.

Table 30 Summary of PFAS Analytical Results in Groundwater Samples from Monitoring Wells and Abstraction Bores

Area	No. of samples analysed	No. of PFAS detected	No of samples exceeding human health IL for PFHxS +PFOS / Max. conc. in µg/L	No of samples exceeding ecological IL* for PFOS / Max. conc. in µg/L	No of samples exceeding of human health IL for PFOA / Max. conc. in µg/L	No of samples exceeding of ecological IL* for PFOA/ Max. conc. in µg/L
Andoom HEQ	14	12	6 / 0.173 µg/L	13 / 0.11 µg/L	0	0
Evans Landing	13	12	4 / 0.645 µg/L	13 / 0.431 µg/L	0	0
Evans Landing Landfill	5	13	3 / 0.333 µg/L	5 / 0.203 µg/L	0	0
Railway Workshop	12	12	1 / 0.225 µg/L	12 / 0.176 µg/L	0	0
Lorim Point	16	12	5 / 2.52 µg/L	15 / 1.44 µg/L	0	0
Weipa Airport	14	11	1 / 0.153 µg/L	13 / 0.088 µg/L	0	0
East Weipa HEQ	12	14	6 / 0.641 µg/L	12 / 0.5 µg/L	0	0
Weipa Township	9	6	0 / 0.0259 µg/L	3 / 0.015 µg/L	0	0

Note: * NEMP (HEPA and DoEE, 2018) 99% species protection – high conservation value systems – fresh and interim marine

7.4.2.1 Andoom HEQ

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F18, Appendix A**. PFAS was detected above the LOR (0.0003 µg/L) in all 14 groundwater samples with 12 PFAS compounds detected. It is noted that the maximum concentrations of three compounds were higher compared to other compounds in the samples analysed. These were PFHxA (0.147 µg/L at AHEQ_MW05), PFPeA (0.243 µg/L at AHEQ_MW05) and 6:2 FtS (0.298 µg/L at AHEQ_MW09).

There were six exceedances of the human health IL for drinking water in the groundwater samples, with the maximum PFHxS+PFOS concentration (0.173 µg/L, 2.5 times the IL) detected in AHEQ_MW06, located hydraulically down-gradient and approximately 300m to the south of the workshop. The other exceedances were in groundwater samples from AHEQ_MW03, AHEQ_MW04, AHEQ_MW05, AHEQ_MW07, AHEQ_MW08 and AHEQ_MW10, which are all located to the south and southwest and hydraulically down gradient of the workshop. All of the groundwater samples that exceeded the human health IL were from monitoring wells that are not used for potable purposes.

There were 13 exceedances of the adopted ecological IL for PFOS and no exceedances of the adopted ecological IL for PFOA.

7.4.2.2 Evans Landing

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F19, Appendix A**. PFAS was detected above the LOR (0.0003 µg/L) in all 13 groundwater samples with 12 different PFAS compounds detected above the limit of reporting.

There were four exceedances of the human health guideline levels for drinking water in the groundwater samples with the maximum PFHxS+PFOS concentration (0.645 µg/L, approximately nine times the IL) detected in ELS_MW18, located approximately 120 m southwest of the SES Training Fire

and Rescue Building. The other exceedances were in groundwater samples from ELN_MW07, ELN_MW09 and ELS_MW19, all located to the west and southwest of the SES Training Fire and Rescue Building.

There were exceedances of the adopted ecological IL for PFOS in all 13 samples. There were no exceedances of the adopted ecological IL for PFOA.

7.4.2.3 Evans Landing Landfill

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F19, Appendix A**. PFAS was detected above the LOR (0.0003 µg/L) in five groundwater samples with 13 different compounds detected. It is noted that a perfluoroalkyl sulfonamide (FOSA) was detected in the sample from MB5, which may be associated with PFAS in waste materials such as packaging rather than AFFF.

Concentrations in three of the five samples (MB5, MB7, MB18) exceeded the human health guideline levels for PFHxS+PFOS with the maximum concentration detected in the sample from MB18 (0.333 µg/L, approximately five times the IL). There were no exceedances of the human health IL for PFOA.

Concentration in all five samples exceeded the adopted ecological IL for PFOS. There were no exceedances of the adopted ecological IL for PFOA.

7.4.2.4 Railway Workshop

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F20, Appendix A**. PFAS was detected above the LOR (0.0003 µg/L) in all 12 groundwater samples with 12 different compounds detected.

There was one exceedance (0.225 µg/L at RWW_MW07) of the human health guideline level for drinking water for PFHxS+PFOS in a monitoring well (which is not used for potable purposes). The adopted ecological IL for PFOS was exceeded in all samples. There was no exceedance of the human health or ecological IL for PFOA.

7.4.2.5 Lorim Point

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F20, Appendix A**. PFAS was detected above the LOR (0.0003 µg/L) in all 16 groundwater samples with 12 different compounds detected.

There were five exceedances of the human health guideline levels for drinking water in the groundwater samples with the maximum PFHxS+PFOS concentration (2.52 µg/L) detected in LPI_MW07, located approximately 350 m to the southwest of the Fire and Rescue buildings. The PFAS concentrations in this well were the highest recorded during the DSI. The other exceedances of the human health guideline levels for drinking water were in groundwater samples from LPI_MW21, LPI_MW27, LPI_MW28 and LPI_MW29. All of the groundwater samples that exceeded the human health IL were from monitoring wells that are not used for potable purposes.

There were 15 exceedances of the adopted ecological IL for PFOS. There were no exceedances of the human health or ecological ILs for PFOA.

7.4.2.6 Weipa Airport

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F21, Appendix A**. PFAS was detected above the LOR in 12 of the 13 groundwater samples with 11 different compounds detected.

There was one exceedance of the human health guideline level for drinking water for PFHxS+PFOS (0.153 µg/L at AFD_MW36). This monitoring well is located approximately 200 m to the south of the eastern portion of the runway.

There were no exceedances of the human health or ecological ILs for PFOA. There was 13 exceedance of the ecological IL for PFOS.

7.4.2.7 East Weipa HEQ

The groundwater analytical results for PFHxS+PFOS concentrations in November 2018 to February 2019 are presented on **Figure F22, Appendix A**. PFAS was detected above the LOR (0.0003 µg/L) in all 12 groundwater samples with 14 different compounds detected.

There were six exceedances of the human health guideline levels for drinking water in the groundwater samples with the maximum PFHxS+PFOS concentration (0.641 µg/L) detected in EWHEQ_MW09 located approximately 400 m to the southwest of the workshop. The other exceedances were in groundwater samples from EWHEQ_MW04 (0.082 µg/L), EWHEQ_MW05 (0.38 µg/L), EWHEQ_MW08 (0.0729 µg/L), RN109710 (0.107 µg/L) and RN78251 (0.16 µg/L).

There were 12 exceedances of the adopted ecological ILs for PFOS. There were no exceedances of the human health or ecological ILs for PFOA.

7.4.2.8 Weipa Township

Nine abstraction bores in the Weipa Township were sampled in February 2019 and are shown on **Figure F23**, **Appendix A**. PFAS was detected in six of these bores with the maximum PFHxS+PFOS concentration detected in SA039 (0.0259 µg/L).

There were no exceedances of the human health or ecological IL for PFOA. There were three exceedances of the adopted ecological IL for PFOS in samples from the nine abstraction bores.

7.4.3 TOPA

PFAS TOPA analysis was conducted on six of the groundwater samples collected during the November 2018 groundwater sampling. The analytical results are presented in **Table T9, Appendix B** and are summarised in **Table 31** below.

Table 31 Summary of PFAS and TOPA Analytical Results in Groundwater Samples

Groundwater Sample	Units	Sum of 28 PFAS (standard analysis)	Sum of 28 PFAS (TOPA)	Sum of TOP C4-C14 Carboxylates and C4-C8 Sulfonates
AHEQ_MW06	µg/L	0.612	0.45	0.29
AFD_MW36	µg/L	0.23	2.13	1.4
ELS_MW18	µg/L	0.834	1.23	0.8
EWHEQ_MW05	µg/L	2.07	6.25	4.09
LPI_MW07	µg/L	3.3	5.79	3.7
RWW_MW07	µg/L	0.665	4.01	2.64

As the sum of the 28 PFAS by TOPA are higher than the sum of the 28 PFAS by standard analysis for five of the samples (Weipa Airport (AFD_MW36), East Weipa HEQ (EWHEQ_MW05), Lorim Point (LPI_MW07) and Railway Workshop (MW07)), this indicates the potential for transformation of precursor compounds at groundwater at these locations.

As the sum of the 28 PFAS by TOPA is lower than the sum of the 28 PFAS by standard analysis at the other location (Andoom HEQ, AHEQ_MW06), this suggests that depletion of oxidant by compounds other than PFAS (e.g. naturally occuring organic material and hydrocarbons) during the standard laboratory digestion step, resulting in insufficient oxidation of PFAS.

7.4.4 Sediment and surface water samples

Co-located sediment and surface water samples were collected during both dry and wet seasons from wash pad at Andoom HEQ, a wash bay discharge outlet at East Weipa HEQ and from locations along the Embley River (adjacent to Evans Landing and Lorim Point) and Beening Creek (adjacent to Weipa Airport). The sediment results are presented in **Table T10, Appendix B** with the surface water results presented in **Table T11, Appendix B**. The results are described in the following subsections.

7.4.4.1 Andoom HEQ Creek Wash pad and Andoom Creek

Co-located surface water and sediment samples were collected from the Andoom Creek wash pad (PR/AND/WS) and at a location along Andoom Creek, 30m downstream of the washpad (PR/AND/WS/DOS). Samples were collected in dry and wet seasons.

PFAS was detected in all four surface water samples with sum of PFAS concentrations between 0.63 and 3.85 µg/L. The main compound present was the fluorotelomer 6:2 FtS in all the samples. There were 15 compounds detected. PFAS concentrations in the downstream samples were higher compared to the PFAS concentrations in surface water at the discharge outlet. There were no exceedances of the human health (for recreational water). There were exceedances of the adopted ecological IL for PFOS in all five surface water samples with a maximum concentration of 0.038 µg/L. There was no exceedance of the ecological IL for PFOA.

The wet season sediment sample from the discharge outlet was not collected as the sampling point was not accessible. PFAS concentrations in all three sediment samples collected during the dry season were similar, with sum of PFAS between 0.014 and 0.017 mg/kg with similar compounds detected. Fluorotelomers (6:2 FtS, 8:2 FtS and 10:2 FtS) were the main compounds present. The results are shown on **Figure F24**, **Appendix A**.

7.4.4.2 Embley River- Evans Landing

Surface water samples were collected from the Embley River adjacent to Evans Landing at three near-shore and three off-shore locations at both high and low tide conditions representative of dry and wet seasons. Sediment samples were collected from the three near shore sampling locations in both dry and wet seasons. The results are shown on **Figure F25**, **Appendix A**. A summary of the results are shown in **Table 32**.

Table 32 Summary of PFAS Results in Surface Water and Sediment Samples at Embley River adjacent to Evans Landing

Location	No. of samples	No. >LOR (0.0003 µg/L)	Max. Conc. of Sum of PFAS	Compounds present	No. of samples exceeding health IL	No. of samples exceeding ecological IL
Surface water						
Near shore, dry season, high tide	3	0	All <LOR	None	0	0
Near shore, wet season, high tide	3	3	0.0037 µg/L	PFOS, PFHxS	0	3
Near shore, dry season low tide	3	1	0.0006 µg/L	PFOS	0	1
Near shore, wet season low tide	3	3	0.0054 µg/L	PFOS, PFHxS, PFPeA	0	3
Offshore, dry season, high tide	3	0	All <LOR	None	0	0
Offshore, wet season, high tide	3	0	All <LOR	None	0	0
Offshore, dry season, low tide	3	0	All <LOR	None	0	0
Offshore, wet season, low tide	3	0	All <LOR	None	0	0
Sediment						
Near shore, dry season)	3	0	All <LOR		0	0
Near shore, wet season	3	0	All <LOR		0	0

The results show the following:

- PFAS was not detected in any of the offshore surface water samples collected during both dry and wet seasons from high and low tide conditions. The offshore samples were collected approximately 120 m from the foreshore.
- PFAS was not detected in near shore samples collected during the dry season at high tide conditions. PFAS was detected in one of the three samples (EMB/EV/NSB) collected during the low tide conditions with PFOS detected at a concentration (0.0006 µg/L), slightly above the LOR suggesting the high dilution factors that naturally occur within this tidal system result in PFAS concentrations reducing to less than the LOR.

- PFAS was detected in all near shore samples collected during the wet season during both high and low tide conditions, with similar maximum sum of PFAS concentrations detected (up to 0.0054 µg/L in EMB/EV/NSC). Three PFAS were detected, PFOS, PFHxS and PFPeA. This suggests the influence of tidal dilution during the wet season is not as strong, possibly due to greater PFAS flux from groundwater and surface water flow.
- PFAS was not detected above the LOR in any of the six sediment samples collected from Evans Landing suggesting that sediments in these areas do not act as sinks for PFAS and PFAS predominantly occurs in the aqueous phase.
- There were no exceedances of the human health guideline levels in the samples from Embley River adjacent to Evans Landing.
- There were exceedances of the adopted ecological IL for PFOS in all six wet season surface water samples and one dry season sample surface water sample. The maximum PFOS concentration detected was 0.039 µg/L in EMB/EV/NSC_Low (collected February 2019). There was no exceedance of the ecological IL for PFOA.

7.4.4.3 Embley River- Lorim Point

Surface water samples were collected from the Embley River adjacent to Lorim Point at three near-shore and three off-shore locations at both high and low tide conditions on two occasions representative of dry and wet seasons. Sediment samples were collected from the three near shore sampling locations in both dry and wet seasons. A summary of the results are shown in **Table 33**. The results are shown on **Figure F25**, **Appendix A**.

Table 33 Summary of PFAS Results in Surface Water and Sediment Samples at Embley River adjacent to Lorim Point

Location	No. of samples	No. >LOR (0.0003 µg/L)	Max. Conc. Sum of PFAS	Compounds present	No. of samples exceeding health IL	No. of samples exceeding ecological IL
Surface water						
Near shore, dry season, high tide	3	2	0.0008 µg/L	PFOS	0	2
Near shore, dry season low tide	3	2	0.0009 µg/L	PFOS, PFHxS	0	2
Near shore, wet season, high tide	3	1	0.0012 µg/L	PFOS	0	1
Near shore, wet season low tide	3	3	0.0464 µg/L	PFOS, PFHxS, PFHxA, PFOA, PFBS, PFPeS, PFHpS, PFPeA PFHpA	0	3
Offshore, dry season, high tide	3	0	All <LOR		0	0
Offshore, dry season, low tide	3	0	All <LOR		0	0
Offshore, wet season,	3	0	All <LOR		0	0

Location	No. of samples	No. >LOR (0.0003 µg/L)	Max. Conc. Sum of PFAS	Compounds present	No. of samples exceeding health IL	No. of samples exceeding ecological IL
high tide						
Offshore, wet season, low tide	3	0	All <LOR		0	0
Sediment						
Near shore, dry season	3	0	All <LOR		0	0
Near shore, wet season	3	1	0.0003 µg/L		0	0

The results show the following:

- PFAS was not detected in any of the offshore surface water samples collected during both dry and wet seasons from high and low tide conditions. The offshore samples were collected between approximately 100 m and 350 m from the foreshore.
- PFAS was detected in four out of six near shore samples collected during the dry season at both high and low tide conditions. The maximum sum of PFAS concentration detected was 0.0009 µg/L with PFOS and PFHxS detected. This suggests the high dilution factors that naturally occur within this tidal system result in PFAS concentrations reducing to less than the LOR.
- PFAS was detected in one of the three near shore samples collected during the wet season and high tide conditions. PFOS was detected at a concentration of 0.012 µg/L. PFAS was detected in all three low tide samples, with a maximum sum of PFAS concentration of 0.464 µg/L detected. Nine different compounds were detected. This suggests the influence of tidal dilution during the wet season is not as strong, possibly due to greater PFAS flux from groundwater and surface water flow.
- PFAS was not detected above the LOR in any of the six sediment samples collected adjacent to Lorim Point suggesting that sediments in these areas do not act as sinks for PFAS and PFAS predominantly occurs in the aqueous phase.
- There were no exceedances of the adopted human health guideline levels in the samples from Embley River adjacent to Lorim Point.
- There were exceedances of the adopted ecological IL for PFOS in five wet season surface water samples and two dry season sample surface water samples. The maximum PFOS concentration detected was 0.019 µg/L in EMB/EV/NSB_Low (collected in February 2019). There was no exceedance of the ecological IL for PFOA.

7.4.4.4 Beening Creek

Co-located sediment and surface water samples were collected from three locations along the Beening Creek, representing upstream, midstream and downstream positions during the dry and wet seasons. The midstream and downstream surface water sampling locations could not be accessed during the dry season. The results are shown on **Figure F26**, **Appendix A**.

PFAS was detected in four of the five surface water samples collected. The maximum sum of PFAS concentration detected was 0.0076 µg/L from the wet season sample from the midstream location primary. The compounds detected were PFOS, PFHxS and PFPeS.

With one exception, all PFAS concentrations in sediment samples were below the LOR (0.0002 mg/kg). The exception was the detection of PFPeA at 0.0007 mg/kg in the sample collected from an upstream position during the dry season (November 2018), which is close to the LOR.

There were no exceedances of the adopted human health ILs in the samples. There were exceedances of the adopted ecological IL for PFOS in four of the five surface water samples with a maximum concentration of 0.004 µg/L. There was no exceedance of the ecological IL for PFOA.

7.4.4.5 East Weipa HEQ Wash Bay Discharge Outlet

At the East Weipa HEQ, co-located surface water and sediment samples were obtained during both wet and dry seasons from the wash bay discharge outlet (PR/EWM/WP), with samples collected approximately 30 m downstream of this point (PR/EWM/WP/DOS) and a further 200 m downstream (PR/EWM/02) (sediment only). The results are shown on **Figure F26**, **Appendix A** and are summarised in **Table 34**.

Table 34 Summary of PFAS Results in Surface Water and Sediment Samples at EWHEQ Wash Bay Discharge Outlet

Location	Media type & time of sampling	Maximum Sum of PFAS Concentration	Compounds detected
Wash Bay Discharge Outlet	Surface water, dry season	3.02 µg/L	6:2 FtS, 8:2 FtS, PFOS, PFHxS, PFHxA, PFOA, PFBS, PFPeS, PFHpA
	Surface water, wet season	0.41 µg/L	6:2 FtS, 8:2 FtS, 4:2 FtS, PFOS, PFHxS, PFHxA, PFOA, PFBS, PFPeS, PFPpS, PFPeA, PFHpA
	Sediment, dry season	0.26 mg/kg	6:2FtS, 8:2 FtS, 10:2 FtS, PFOS, PFHxS, PFHxA, PFPeA
	Sediment, wet season	0.011 mg/kg	6:2FtS, 8:2 FtS, 10:2 FtS, PFOS, PFBS
30m downstream of wash bay discharge outlet	Surface water, dry season	1.31 µg/L	6:2 FtS, 8:2 FtS, PFOS, PFHxS, PFHxA, PFOA, PFBS, PFPeS, PFPeA, PFHpA
	Surface water, wet season	0.77 µg/L	6:2 FtS, 8:2 FtS, PFOS, PFHxS, PFHxA, PFOA, PFBS, PFPeS, PFPpS, PFPeA, PFHpA, PFNA, PFDcA
	Sediment, dry season	0.035 mg/kg	6:2 FtS, 8:2 FtS, 10:FtS, PFOS, PFHxS, PFHxA, PFOA, PFPeA, PFNA, PFDcA, PFHpA, PFUnA
	Sediment, wet season	0.011 mg/kg	6:2 FtS, PFOS, PFDcA
200m downstream of wash bay discharge outlet	Sediment, dry season	<LOR	None
	Sediment, wet season	<LOR	None

PFAS was detected in surface water samples from the two sampling locations during both dry and wet seasons with sum of PFAS between 0.41 and 3.02 µg/L. The highest PFAS concentration was detected in surface water at the discharge point in the dry season and the main compounds present were fluorotelomers, mainly 6:2 FtS.

PFAS was detected in the two sediment samples collected from the discharge outlet during both wet (0.26 mg/kg sum of PFAS) and dry (0.011 mg/kg sum of PFAS) seasons. The main compounds present in the dry season sample were also fluorotelomers with 10:2 FtS (0.228 mg/kg) the principal compound present.

PFAS concentrations in the sediment samples collected from 30m downstream of the wash bay outlet in the dry and wet seasons were at similar concentrations to each other (sum of PFAS were 0.011 mg/kg and 0.035 mg/kg). PFAS was not detected above the LOR in the dry and wet season sediment samples from a location approximately 200m downstream of the wash bay discharge outlet (PR/EWM/02).

There were no exceedances of the human health ILs in the samples. There were exceedances of the adopted ecological IL for PFOS in all four surface water samples with a maximum concentration of 0.005 µg/L. There was no exceedance of the ecological IL for PFOA.

8.0 Discussion

8.1 Geological and Hydrogeological Conditions

Water level contours show that groundwater in the shallow aquifer flows towards the foreshore of the Mission and Embley Rivers. The creeks are other points of discharge from the aquifer which are fed by springs issuing water from aquifer sands. Water is lost from all around the periphery of the aquifer, with creeks causing localised drawdown of the water table (Coffey & Hollingsworth, 1971). When aquifer losses to the sea and rivers exceed rainfall, the water levels drop in the aquifer. This indicates limited effective storage in the sand aquifer. Another main natural water loss from the aquifer is through evapotranspiration. The groundwater elevation data collected during this investigation has identified significant seasonal variation in groundwater elevation which varied by approximately 2 m between the wet and dry season measurements, with the exception of the Andoom HEQ and East Weipa HEQ areas, where the surface water level varied by approximately 5 and 7 m, respectively. During heavy wet seasons (> 2,000 mm) the water table can potentially rise to the surface resulting in surface runoff.

Migration of contaminants in groundwater will be influenced by natural groundwater gradients and by continuous abstraction of bores. If abstraction is not considered, then the natural groundwater gradient will result in migration of contaminants in the directions indicated below:

- Andoom HEQ in a south / south westerly direction
- Evans Landing / Evans Landing landfill: in a southerly direction
- Railway Workshop: in a south westerly direction
- Lorim Point: in a south / south westerly direction
- Airport: in a south westerly direction
- East Weipa HEQ: in a south westerly direction.

8.2 Findings of the Biota Investigation and Interim Risk Assessment

The interim risk assessment (AECOM, 2018b) reported that PFAS concentrations in all biota samples analysed in 2018 (total of 83) were at least an order of magnitude below the adopted guidelines. The reported PFAS concentrations for all co-located surface water and sediment samples analysed were below the laboratory LOR. Based on the available information, the Tier 1 assessment of biota, sediment and surface water concluded that there is negligible risk to human and ecological health from the consumption of aquatic biota. These results provide a line of evidence that PFAS contamination is not widespread in the receiving environment.

8.3 Interpretation of Soil Analytical Results

This section presents an interpretation of the soil results and combines data from the current (November 2018) investigation with analytical results obtained from the previous investigation and monitoring in 2017 and 2018. The historical soil analytical results are presented in **Table T12**.

8.3.1 Statistical Summary

A summary of PFHxS+PFOS concentrations in soil in different depth intervals is shown in **Table 35**. This shows that PFAS was more frequently detected in soil samples in the 0.0 to 0.2 m depth interval (in approximately 70% of samples) and in the 0.2 to 1.0 m depth interval (in 33% of samples). PFAS was infrequently detected below 1.0 mbgl (in 22% of samples). The table also shows that the higher concentrations of PFAS are present in the near-surface soils, 0.0 to 0.2 mbgl, with decreasing concentrations (as indicated by maximum and median values) with increasing depth. The 95% upper confidence interval (UCL) is similar for the 0.0 to 0.2 mbgl and 0.2 to 1.0 mbgl depth interval, which is due to the presence of PFAS in soil samples in the Lorim Point Industrial Precinct. The higher PFAS concentrations in the shallower soil interval indicate residual PFAS is generally limited to the upper soil profile.

Table 35 Summary of sum of PFHxS and PFOS in Soil Samples

Depth Interval	PFHxS+PFOS in Soil (mg/kg)			
	0.0-0.2 mbgl	0.2-1.0 mbgl	1.0-2.0 mbgl	>2.0 mbgl
No of samples	90	39	16	16
No > LOR	62	13	5	2
Maximum	2.45	2.06	0.105	0.003
Mean	0.0848	0.0759	0.00773	0.00015
Median	0.0034	0.0001	0.0001	0.0001
Standard Deviation	0.3	0.345	0.026	0.0001
95%UCL	0.223	0.421	0.073	0.0003

Note: * 95% UCL shows the 95th percentile upper confidence level (UCL) of the arithmetic mean. These have been calculated using US EPA ProUCL v5.1.002. Samples below LOR were assumed to be equal to the LOR.

8.3.2 Evaluation of Statistical Distribution of PFAS in Soil Samples

A summary of the average composition of PFAS in soil from the Andoom HEQ, Lorim Point and East Weipa HEQ areas is summarised in **Table 36**. The statistical analysis considered samples where PFAS was detected at concentrations greater than 0.1 mg/kg sum of PFAS. As PFAS concentrations in soil samples from Evans Landing, the Railway Workshop and Weipa Airport were all below this threshold, statistical analysis of the distribution was not undertaken.

Table 36 Summary of ratios of PFAS in soil samples in different primary source areas

PFAS	Andoom HEQ (n = 5)	East Weipa HEQ (n=6)	Lorim Point (n=8)
PFHxS+PFOS	73%	65%	80%
6:2 FTS	2%	12%	10%
PFHxA	8%	8%	1%
PFBS	6%	4%	0%
PFOA	3%	2%	1%
PFBA	3%	0%	0%
PFPeS	4%	2%	0%
PFHpS	2%	2%	1%
PFPeA	2%	2%	1%
8:2 FTS	0%	1%	2%
PFDS	0%	0%	2%
PFHpA	1%	1%	0%

The results indicate PFAS in soil in all three primary source areas are dominated by PFHxS and PFOS, with these compounds making up between 65% and 80% of the detected PFAS. The main differences between the other compounds are as follows:

- The fluorotelomer 6:2 FtS comprises between 10 and 12% of the detected PFAS in the soil in samples at East Weipa HEQ and Lorim Point, but only 2% at Andoom HEQ. 6:2 FtS is a known precursor, which can transform to PFHxA (DEHP, 2016).
- PFHxA and PFBS are both present in soil samples at Andoom and East Weipa HEQ comprising 12-14% of the total PFAS, but are present in soil samples from the Lorim Point area at 1%.

Overall, the distribution of PFAS in soil at the two heavy equipment workshops at Andoom and East Weipa are approximately similar, which may reflect similar types of AFFFs that have been used historically. The soil samples from Lorim Point have a slightly different mixture, which may indicate different type(s) of AFFF may have been used historically in this area.

8.3.3 Leachability of PFAS in Soil Samples

A comparison of PFHxS in soil and leachate (post-TOPA) for all available data is presented in **Table 37**. Historical leachate results are shown in **Table T13**, **Appendix B**. The results show sum of PFHxS and PFOS concentrations in soil between 0.0007 and 2.45 mg/kg. Following leaching of these soil samples, sum of PFHxS and PFOS concentrations in leachate were between 0.02 and 154 µg/L. The results show that the PFAS present in the soil in all primary source areas is readily leachable to surface water and groundwater.

Table 37 Summary of PFAS Leachate Analytical Results in Soil Samples

Sample	Date of Sampling	Sum of PFHxS and PFOS (soil (mg/kg)	Sum of PFHxS and PFOS (µg/L) Leachate
AHEQ SS04 0.0-0.1	14/11/2018	1.14	32.3
ELN MW10 0.4-0.5	15/11/2018	0.0041	0.1
RWW SS02 0.1-0.2	14/11/2018	0.0007	0.02
LP SS07 0.1-0.2	17/11/2018	0.31	7.57
EWHEQ SS02 0.0-0.1	19/11/2018	0.47	7.87
AHEQ-SS12 0.1	19/10/2017	0.006	0.096
AP-SS03 0-0.1	18/10/2017	0.0024	0.181
EWHEQ-SS16 0.0-0.1	19/10/2017	0.0084	0.11
FR-SS08 0-0.1	18/10/2017	0.056	0.561
FRTP 12 0.1-0.2	18/10/2017	2.45	154

8.3.4 Extent of PFAS in Soil

8.3.4.1 Andoom HEQ

Collectively, the 2017 and 2018 investigations have characterised 12 sampling locations at the Andoom HEQ with near surface soil samples collected from areas to the south, southwest and north of the workshop. The sampling locations were designed to provide spatial coverage of the area surrounding the workshop at locations which may be impacted by the historical discharge to ground of AFFFs in this area. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas. The distribution of sum of PFHxS and PFOS in soil around the Andoom HEQ is shown in **Figure F27**, **Appendix A**.

The results show that the highest PFAS concentrations detected were in soil bore AHEQ_SS04 located approximately 60 m to the south of the eastern portion of the workshop. The sum of PFAS concentration in the 0.0-0.1 mbgl sample was 1.26 mg/kg. The sum of PFAS concentration in a deeper sample in this bore from 0.1 to 0.2 mbgl was approximately 50% lower, and this indicates that a decrease in concentration with increasing depth. The local lateral extent of this impacted area has not been ascertained as the nearest soil bores are tens of metres away.

Localised elevated PFAS concentrations in near surface soils (approximately 0.24 mg/kg sum of PFAS) were also detected in samples from AHEQ_SS01 at 0.0 to 0.1 mbgl, located immediately south of the eastern portion of the workshop and AHEQ_SS06 at 0.0-0.1 mbgl located immediately north of the western portion of the workshop. A summary of sum of PFHxS and PFOS concentrations in soil samples collected from bores advanced in 2017 and 2018 are summarised in **Table 38**.

Table 38 Summary of sum of PFHxS and PFOS in Soil Samples in Andoom HEQ

Area	Depth Interval (mbgl)	No of samples	No. of samples >LOR	Maximum concentration of PFHxS+PFOS (mg/kg)
Andoom HEQ	0.0-0.2	15	15	1.14
	0.2-1.0	5	2	0.0076
	1.0-2.0	1	0	0
	>2.0	4	0	0

As discussed in **Section 8.3.2**, the predominant PFAS present are PFOS and PFHxS.

8.3.4.2 Evans Landing

The DSI has characterised soil at nine separate locations in the area. The sampling locations were designed to provide spatial coverage of the area at locations which may be impacted by the historical use of AFFFs in this area. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas.

PFAS concentrations were detected in approximately 50% of soil samples. As the concentrations detected are considered to be close to the limit of reporting in all soil bores, the soil investigation has not identified any localised areas of soil with PFAS within this potential source area.

A summary of sum of PFHxS and PFOS concentrations in soil samples collected from different depth intervals in the bores advanced in 2018 are summarised in **Table 39**.

Table 39 Summary of Sum of PFHxS and PFOS in Soil Samples in Evans Landing

Area	Depth Interval (mbgl)	No of samples	No. of samples >LOR	Maximum concentration of PFHxS+PFOS (mg/kg)
Evans Landing	0.0-0.2	10	7	0.0025
	0.2-1.0	5	2	0.0041
	1.0-2.0	3	0	0
	>2.0	2	0	0

8.3.4.3 Railway Workshop

The DSI has characterised soil at seven separate locations in the area. The sampling locations were designed to provide spatial coverage of the area at locations which may be impacted by the historical use of AFFFs in this area. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas.

PFAS concentrations were detected in 40% of the soil samples. As all the detected concentrations are close to the limit of reporting in all soil bores (maximum sum of PFAS of 0.007 mg/kg in RWW_SS02 at 0.0 to 0.1 mbgl), the soil investigation has not identified any localised areas of soil with PFAS within this potential source area.

A summary of sum of PFHxS and PFOS concentrations in soil samples collected from different depth intervals in the bores advanced in 2018 are summarised in **Table 39**.

Table 40 Summary of Sum of PFHxS and PFOS in Soil Samples in Railway Workshop

Area	Depth Interval (mbgl)	No of samples	No. of samples >LOR	Maximum concentration of PFHxS+PFOS (mg/kg)
Railway Workshop	0.0-0.2	5	3	0.0007
	0.2-1.0	2	0	0
	1.0-2.0	0	0	0
	>2.0	3	1	0.0005

8.3.4.4 Lorim Point

Collectively, the 2017 and 2018 investigations have characterised 26 sampling locations at the Lorim Point area, with near surface soil samples collected from locations designed to target potential areas identified in the PSI where AFFF, potentially containing PFAS, may have been discharged to ground. These locations were identified in the PSI (Golder, 2018a). The sampling locations were designed to provide spatial coverage of the area to provide lateral extent of soil contamination. The distribution of sum of PFHxS and PFOS in soil around the Andoom HEQ is shown in **Figure F28**, **Appendix A**.

The results show that the Lorim Point area had the highest PFAS concentrations detected during the soil investigations, with the local areas of impact in soil bores to the south and southwest of the F&R building. The highest concentrations were detected in bores advanced during the 2017 investigation, with the highest concentrations detected soil samples in FRTP10, FRTP11 and FRTP12, with the maximum concentration detected at FRTP12 at 0.0 to 0.1 mbgl (2.55 mg/kg sum of PFAS). A deeper soil sample from 0.4 to 0.5 mbgl had a similar, but slightly lower sum of PFAS concentration (2.38 mg/kg).

The lateral extent of hot spots with higher PFAS concentrations in soil is likely to be localised to discrete areas where AFFF has been discharged to ground. PFAS was detected in soil samples from bores across the general operational Lorim Point area indicating widespread impact as a result of the historical activities in the area. As indicated in **Section 8.3.3**, PFAS is readily leachable and the soils in the F&R area are considered to have the potential to act as a source of PFAS to overland surface water as well as groundwater.

A summary of sum of PFHxS and PFOS concentrations in soil samples collected from bores advanced in 2017 and 2018 are summarised in **Table 41**.

Table 41 Summary of sum of PFHxS and PFOS in Soil Samples in Lorim Point Industrial Precinct

Area	Depth Interval (mbgl)	No of samples	No. of samples >LOR	Maximum concentration of PFHxS+PFOS (mg/kg)
Lorim Point	0.0-0.2	22	21	2.45
	0.2-1.0	8	7	2.06
	1.0-2.0	7	3	0.105
	>2.0	4	1	0.0005

8.3.4.5 Weipa Airport

Collectively, the 2017 and 2018 investigations have characterised soil at 28 separate locations. The sampling locations were designed to provide spatial coverage of the area at locations which may be impacted by the historical use of AFFFs in this area (based on the potential discharge areas presented in the PSI, Golder, 2018a).

PFAS concentrations were detected in two of 42 soil samples analysed. As all the detected concentrations are close to the limit of reporting in all soil bores (maximum sum of PFAS of 0.024 mg/kg in AP_SS03 0.0 to 0.1 mbgl), the soil investigation has not identified any localised areas of soil with PFAS within this potential source area. A summary of sum of PFHxS and PFOS concentrations in soil samples collected from different depth intervals in the bores advanced in 2017 and 2018 is presented in **Table 42**.

Table 42 Summary of Sum of PFHxS and PFOS in Soil Samples in Weipa Airport

Area	Depth Interval (mbgl)	No of samples	No. of samples >LOR	Maximum concentration of PFHxS+PFOS (mg/kg)
Weipa Airport	0.0-0.2	22	1	0.0024
	0.2-1.0	15	1	0.0003
	1.0-2.0	2	0	0
	>2.0	3	0	0

8.3.4.6 East Weipa HEQ

Collectively, the 2017 and 2018 investigations have characterised 17 sampling locations at the East Weipa HEQ with near surface soil samples collected from areas to the south, southwest and north of the workshop. The sampling locations were designed to provide spatial coverage of the area surrounding the workshop at locations which may be impacted by the historical use of AFFF in this area. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas.

The results show that the highest PFAS concentrations detected in soil were in an unknown sample reported in PSI (Golder, 2018a), which recorded 1.27 mg/kg sum of PFAS. Soil samples from two bores (EWHEQ_SS01 and EWHEQ_SS02) located to the south of the workshop had elevated concentrations relative to the other soil samples. Sum of PFAS in the deeper sample at EWHEQ_SS01 (at 0.1 to 0.2 mbgl) was a factor of two higher than the shallower sample (collected from 0.0 to 0.1 mbgl). PFAS concentrations were detected in soil bores advanced to the north, west and southwest of the workshop with lower concentrations detected relative to EWHEQ_SS01 and EWHEQ_SS02. These results indicate the presence of localised PFAS impacts in near surface soil across the East Weipa HEQ area. A summary of sum of PFHxS and PFOS concentrations in soil samples collected from different depth intervals in the bores advanced in 2017 and 2018 are summarised in **Table 43**.

Table 43 Summary of sum of PFHxS and PFOS in Soil Samples in East Weipa HEQ

Area	Depth Interval (mbgl)	No of samples	No. of samples >LOR	Maximum concentration of PFHxS+PFOS (mg/kg)
East Weipa HEQ	0.0-0.2	16	15	0.47
	0.2-1.0	4	2	0.0064
	1.0-2.0	3	1	0.0135
	>2.0	0	0	0

8.3.5 Summary

The soil investigations in 2017 and 2018 have identified the presence of areas of soil with locally higher PFAS concentrations (above ecological guideline levels industrial landuse) in shallow soil at three of the potential primary source areas (Andoom HEQ, Lorim Point and East Weipa HEQ). The soil samples were collected from locations across the open areas at these facilities. PFAS concentrations in 11% of the samples exceeded the ecological guideline level for industrial landuse (maximum of 2.5 mg/kg in a soil sample from Lorim Point), however, none of the soil samples exceeded human health guidelines levels for industrial landuse.

The results indicate localised discrete areas of PFAS are present in soil at these three facilities. Results indicate the higher concentrations of PFAS were detected in near surface soil. Relatively minor PFAS impacts (close to or below laboratory limit of reporting) were detected in soil samples from across Weipa Airport and the Railway Workshop. The results in these source areas are not considered to be consistent with large sources of PFAS in soil. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas.

8.4 Interpretation of Groundwater Analytical Results

8.4.1 Distribution of Types of PFAS in Potential Primary Source Areas

Evaluation of the PFAS fingerprints in groundwater in each potential primary source area indicates that different PFAS compositions are present in groundwater samples within these potential source areas. The main PFAS present in groundwater are either PFHxS+PFOS or 6:2 FtS. This is summarised in **Table 44**. Data from the DSI and historical (2017 to 2018) datasets (presented in **Table T14, Appendix B**) has been considered.

Table 44 Summary of Distribution of PFAS Groundwater Samples in Different Potential Primary Source Areas

Potential Source Area	Area / wells with PFHxS and PFOS as main compounds present	Area / wells with 6:2 FtS as main compound present
Andoom HEQ	Wells close to the workshop and hydraulically down-gradient to the S and SW. (AHEQ MW03-MW08, MW10) PFHxS+PFOS 13-51%, PFPeA 6-42% PFHxA 6-26%, PFHpA 6-26%	Wells to the N, E and SE (AHEQ MW09, MW11, ASB MW08, MW10, MW21, MW22) 6:2 FtS 94-99%
Evans Landing	Wells to the W, SW and S of the SES Training Area (ELN MW04, ME07, MW09, ELS MW18, MW19, MW21, MW25, MW32) PFHxS+PFOS 63-74%, 6:2 FtS 2-14%	Wells at and N of the SES Training Area (ELN MW10, ELS MW28, MW29) and wells to the N and W (ELN MW06, ELN MW30) 6:2 FtS 58-76%, PFHxS+PFOS 2-29%
Evans Landing Landfill	Wells to the W, SW and S of the landfill (i.e. hydraulically down-gradient). PFHxS+PFOS 63-74%, PFOA 10-12%, PFBS 6-9%	None.
Railway Workshop	Well to the SW of the workshop (MW01, SA110) PFHxS+PFOS 37-74%, PFPeA 17-30%, PFHxA 19-23%	Wells N, E and W of the workshop (RWW MW02-MW08) 6:2 FtS 36-95%, PFHxS+PFOS 2-36%
Lorim Point	Wells to the W and SW of the F&R area (i.e. hydraulically down-gradient) (LPI MW07, MW21, MW27-30) PFHxS+PFOS 41-83%, 6:2 FtS 2-38%	Wells to the N, E and S of the F&R area (LPI MW19, MW26, MW31, MW32) 6:2 FtS 62%, PFHxS+PFOS 29%
Weipa Airport	Wells to the S, W and SW (i.e. hydraulically down-gradient) of the airport (AFD MW36, ALF MW02, MW03, MW06, MW07) PFHxS+PFOS 67%, PFBS 10%	Well to the S and E (AP02, AFD MW37, ALF MW01, ALF MW04). Note these all have low concentrations close to the LOR
East Weipa HEQ	Wells to the N, S, W and SW of the workshop (EWHEQ MW01-MW03, MW04-MW07, MW09) PFHxS+PFOS 18-49%, PFPeA 18-35%, PFHxA 10-23%	Wells to the S and SW of the workshop (EWHEQ MW04 and EWHEQ MW08) 6:2 FtS 54-61%, PFHxS+PFOS 7-26%, PFPeA 1-19%, PFHxA 1-10%

The different main type of PFAS across the investigation areas may be due to the historical uses of different type of firefighting foam, which contained different fluorinated compounds as the active ingredients. The detection of PFHxS+PFOS appears to be associated with areas hydraulically down-gradient of the potential primary source areas, in particular areas where firefighting training has occurred (i.e. Lorim Point, Evans Landing). The fluorotelomer 6:2 FtS has been detected as the main compound at relatively higher concentration (e.g. >0.09 µg/L) in groundwater from monitoring wells close to the three workshops (Andoom HEQ, East Weipa HEQ and Railway Workshop) and also in wells hydraulically up-gradient or cross-gradient of all the potential primary source areas. The fluorotelomer 6:2 FtS has the potential to transform to PFHxA.

8.4.2 Extent of PFAS in Groundwater

For the purposes of this evaluation, concentrations of the different types of PFAS detected during the monitoring events conducted between October 2017 and February 2019 have been used to inform the

assessment of the extent of PFAS in each of the potential primary source areas. Historical groundwater analytical data are presented in **Table T14**, **Appendix B**.

8.4.2.1 Andoom HEQ

Evaluation of the groundwater analytical dataset indicated all seven monitoring wells located hydraulically down-gradient (south and southwest) of the workshop had concentrations of PFHxS+PFOS that exceeded the drinking water guideline level in the range 0.07-0.17 µg/L during monitoring events in 2017 and 2018. PFHxS and PFOS were the main compounds present in groundwater from these wells. The well furthest down-gradient is AHEQ MW10, located approximately 750 m distance from the workshop. The sum of PFHxS and PFOS in AHEQ_MW10 was 0.159 µg/L, which exceeded the human health drinking water level by a factor of approximately two. The results indicate that the Andoom HEQ area is a source of PFHxS and PFOS in groundwater with the area of groundwater impact likely to be located hydraulically down-gradient (to the southwest) of the workshop.

The PSI (Golder, 2018a) identified that historical surface water discharge from the workshop was to ground, which flowed overland to the south and southwest towards Saleng Tea Tree Swamp located approximately 800 m to the southwest of the workshop. A surface water sample was collected in 2018 from the area of the swamp and PFAS was not detected (see **Table T15**, **Appendix B**).

Groundwater in monitoring wells located more than 250m from the workshop to the northwest, north, northeast, east and southeast (i.e. AHEQ_MW09, AHEQ_MW11, AHEQ_MW21, and ASB_MW08, ASB_MW10, ASB_MW22) had sum of PFAS concentrations in the range 0.05 to 0.31 µg/L, with mainly 6:2 FtS present. This possibly reflects the historical inadvertent discharge of AFFF from fire suppression systems to ground across the Andoom mining area as described in the PSI (Golder, 2018) (see **Section 3.5.1**).

Collectively, the groundwater results have established the lateral extent of the area of groundwater impacted by PFHxS+PFOS to the north, east and south of the workshop. The lateral extent to the west of the workshop and to the southwest beyond AHEQ MW10 has not been established.

8.4.2.2 Evans Landing

The highest PFAS groundwater concentrations (sum of PFAS) detected was in monitoring well ELS_MW18, located to the southwest of the SES Training Fire and Rescue Building and north of bulk fuel storage. One of the highest PFAS concentrations was also detected in ELN_MW09 located to the east of a bulk fuel storage area. Groundwater in samples collected from monitoring wells to the southwest of ELN_MW09 and southwest of ELS_MW18 had PFHxS and PFOS as dominant compounds present which exceeded the drinking water guideline level in ELN_MW07, ELN_MW09, ELS_MW18, ELS_MW19. An interpretation of extent of PFHxS+PFOS in groundwater is shown in **Figure F30**, **Appendix A**.

These results suggest a source area close to ELS_MW18 and ELN_MW09. It is speculated that historical firefighting training may have occurred in these open area. There were limited soil bores advanced in these areas during the investigation as the historical information included in Golder (2018a) did not reference a potential source of AFFF in this area as this information was not recorded.

Groundwater samples from monitoring wells located approximately 200m north, west and southeast of the ELN MW10/ELS MW29 area (i.e. ELN_MW06, ELN_MW30, ELN_MW28) had lower PFAS concentrations (i.e. close to LOR), which were dominated by 6:2 FtS. The lateral extent of the area of PFHxS and PFOS impact in the Evans Landing area is considered to be characterised to the north, east and west by the non-exceedance of PFHxS+PFOS in groundwater from monitoring wells in these areas and by the Embley River to the south.

8.4.2.3 Evans Landing Landfill

Groundwater results in February 2019 have indicated PFHxS+PFOS concentrations exceeded the drinking water guideline level (0.08-0.33 µg/L) in the three monitoring wells located to the southwest and hydraulically down-gradient of the landfill. This indicates that the landfill is a source of PFAS in groundwater, with concentrations at similar magnitudes to other potential source areas such as the Railway Workshop and Weipa Airport. The lateral extent of the area of groundwater impacted by PFAS is characterised to the southeast by the lower PFAS concentrations in groundwater from MB9,

and to the northwest by the PFAS concentrations in groundwater from MB13. The Embley River is located to the southwest of the landfill.

8.4.2.4 Railway Workshop

PFHxS+PFOS concentrations have been detected in at concentrations above the drinking water guideline level in two monitoring wells (RWW_MW01 and RWW_MW07) located less than 150 m to the southwest of the Railway Workshop during the monitoring in 2017 and 2018. Relatively lower PFHxS+PFOS concentrations (<0.015 µg/L) were detected in groundwater samples from the other monitoring wells.

PFAS has been characterised in groundwater around the workshop. The results suggest the area where AFFF was potentially released to ground is in the vicinity of RWW_MW01. The localised extent of the elevated concentrations (above human health guidelines) to the southwest and west is uncertain.

8.4.2.5 Lorim Point

Groundwater at Lorim Point has the highest PFAS concentrations out of the potential primary source areas. The higher PFHxS+PFOS concentrations detected in 2018 were in monitoring wells located directly between the F&R building and the Embley River, with 4.1 µg/L PFHxS+PFOS in LPI_MW08, approximately 200m southwest of the F&R building. The concentration of PFHxS+PFOS was 2.8 µg/L in a monitoring well (LPI_MW04) located close to the Embley River, approximately 450m southwest of the F&R facility. This indicates a plume extends from the F&R Building towards the river, see **Figure F31**, **Appendix A**.

The lateral extent of the plume has been characterised to the north, east and west by the presence of lower PFAS concentrations in up- and cross gradient monitoring wells. Groundwater samples in monitoring wells to the north and east of the plume had PFHxS+PFOS concentrations below drinking water guideline levels. PFHxS+PFOS concentrations in groundwater samples from monitoring wells to the west of the plume (LPI_MW28, LPI_MW29) exceeded the drinking water guideline level, however, concentrations are more than an order of magnitude lower compared to the concentrations detected in LPI_MW07 in 2019 and LPI_MW08 in 2018. None of the groundwater samples from potable abstraction bores at Lorim Point had PFAS concentrations that exceeded the drinking water guideline level.

8.4.2.6 Weipa Airport

PFHxS+PFOS concentrations were detected in excess of the drinking water guideline level in samples from one monitoring well (AFD_MW36) located approximately 200m to the south of the eastern portion of the runway during monitoring events in October 2017 and November 2018. Much lower PFHxS+PFOS concentrations (<0.048 µg/L) were detected in groundwater from the other monitoring wells hydraulically down-gradient of the airport. The lateral extent of PFAS is characterised hydraulically down-gradient of AFD_MW36, to the southwest and in other cross gradient directions (east and west of AFD_MW36). It is noted that PFAS concentrations were much lower (0.003 µg/L PFHxS+PFOS) in a monitoring well (AFD MW22) located <20m to the north of ADF_MW36. These results suggest localised impact in the vicinity of this monitoring well,

8.4.2.7 East Weipa HEQ

Groundwater results have indicated PFHxS+PFOS concentrations in excess of the drinking water guideline level (0.07-0.64 µg/L) in five monitoring wells located to the southwest and hydraulically down-gradient of the workshop during the monitoring events in 2017 and 2018. This indicates that the workshop is a potential source of PFAS in groundwater. The lateral extent of the area of groundwater impacted by PFAS has been characterised to the southwest by the non-exceedance of PFHxS+PFOS guideline level in abstraction bore SA005, which is located approximately 400m southwest of the EWHEQ. The lateral extent has been characterised around the workshop to the northwest, north, east and south by EWHEQ_MW01, EWHEQ_MW06 and EWHEQ_MW07. The extent has not been delineated cross-gradient to the west due to the lack of monitoring wells in this area.

8.4.3 Potable Abstraction Bores

The network of potable abstraction bores consists of 22 bores. The maximum sum of PFHxS and PFOS concentrations detected in these bores over the monitoring period (October 2017 to February

2019) is shown in **Table 45**. This table shows that none of the bores had detections of PFAS that exceeded the NEMP drinking water guideline level.

Table 45 Summary of Results in Potable Abstraction Bores

Bore	Nearest Primary Source Area	No. of samples collected between 2017 and 2019	Maximum sum of PFHxS and PFOS Concentration (µg/L)	No of exceedances of NEMP (HEPA 2018) [0.07 µg/L]
SA091	Andoom HEQ	5	0.003	0
SA092		2	0.005	0
SA093		4	0.006	0
SA110	Railway Workshop	4	0.015	0
SA013	Lorim Point F&R / Railway Workshop	5	0.009	0
SA017		5	0.012	0
SA020		5	0.011	0
SA012	Lorim Point F&R	7	0.0199	0
SA014		6	0.0035	0
SA015		6	0.048	0
SA009	Weipa Airport	4	0.009	0
SA026		6	0.048	0
SA027	East Weipa HEQ	6	0.045	0
SA036	Weipa Township	5	0.002	0
SA037		5	<0.002	0
SA038		5	0.0006	0
SA039		5	0.032	0
SA041		5	0.004	0
SA107		5	0.0012	0
SA349		5	<0.002	0
SA350		5	0.005	0
SA351		4	0.008	0

8.4.4 Evaluation of Groundwater Trends

There is a limited dataset for PFAS concentrations in groundwater at the site, with monitoring events occurring in October 2017, June/July 2018 and November 2018[4]. Weipa experiences large seasonal changes in groundwater elevations (approximately 2 m to 7 m difference in hydraulic head) and the monitoring events that have occurred to date are considered to represent dry season conditions (two rounds represent end of dry season (October 2017 and November 2018) and one event representing midway through the dry season (July 2018). There is a larger dataset for abstraction bores, which have been monitored on up to six occasions and this provides information on trends.

Overall, there is a lack of wet season information to inform the effect of seasonality on PFAS concentrations and it is noted that access to some of the bores/well during the wet season is limited due to safety considerations. Where monitoring wells have been sampled on only two occasions, it is

[4] Potable bores and a small number of monitoring wells were monitored in February 2019, which is considered representative of the wet season.

considered that there is insufficient data to indicate trends and it is not possible to assess if the change in concentration is a reflection of the variability in PFAS concentrations. Notwithstanding these limitations, for completeness, groundwater results in the potential primary source area for each of the sampling events are shown in **Chart 2** to **Chart 7**. Key observations of the groundwater results over time are listed below.

- **Andoom HEQ-** PFHxS+PFOS concentrations in the abstraction bores have been monitored on up to five occasions and show steady concentrations. Four of the groundwater monitoring wells have been monitored on two occasions in the dry season (AHEQ_MW02, AHEQ_MW04, AHEQ_MW05 and AHEQ_MW06) and results showed slightly higher concentrations in the second monitoring event.
- **Evans Landing-** Five of the groundwater monitoring wells have been monitored on two occasions during the dry season. These results show similar or lower concentrations in the second monitoring event.
- **Railway Workshop-** PFHxS+PFOS concentrations in the abstraction bores have been monitored on up to five occasions and show steady concentrations. One of the monitoring wells (RWW MW01) shows a decrease in concentration.
- **Lorim Point-** The graph focuses on the monitoring wells with higher concentrations with a mixture of trends present, which could reflect variability in the PFAS concentrations.
- **Weipa Airport-** Results in abstraction bores show stable concentrations. Two of monitoring wells, which were sampled on two occasions in the dry season show lower concentrations in the second monitoring event.

The groundwater trends in abstraction bores in Weipa Township are shown in **Chart 8**. Groundwater results in the abstraction bores over five monitoring events show steady concentrations that are below the drinking water guideline level (indicated by an orange dashed line).

Additional monitoring data would be required to establish the longer term PFAS trends and the effect of seasonality in groundwater around the potential primary source areas.

Chart 2 PFHxS+PFOS concentrations in groundwater at Andoom HEQ: October 2017 to February 2019

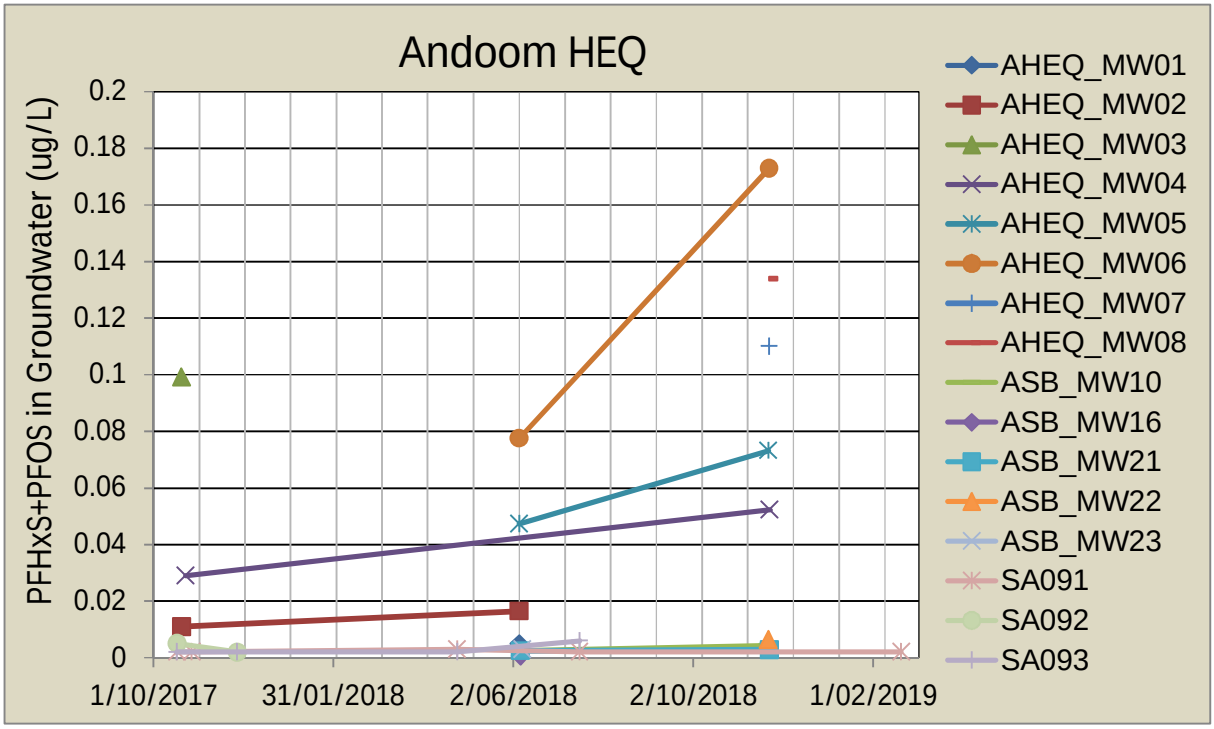


Chart 3 PFHxS+PFOS concentrations in groundwater at Evans Landing: October 2017 to February 2019

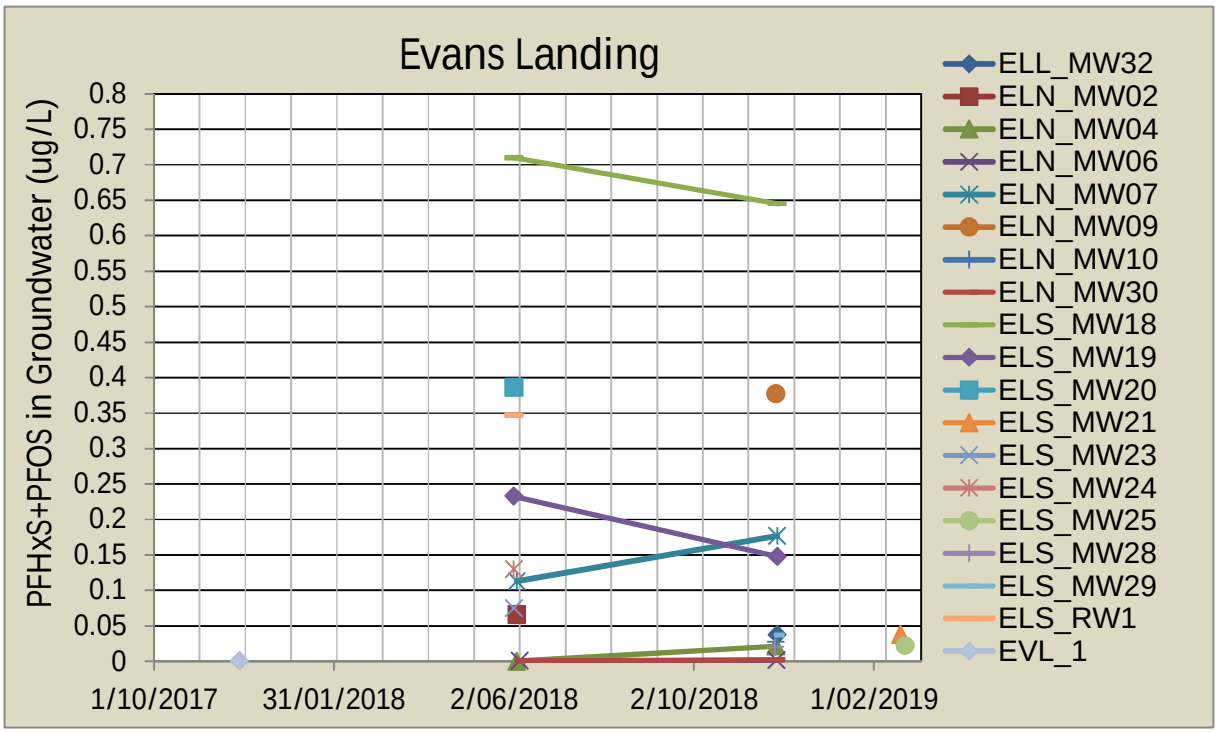


Chart 4 PFHxS+PFOS concentrations in groundwater at Railway Workshop: October 2017 to February 2019

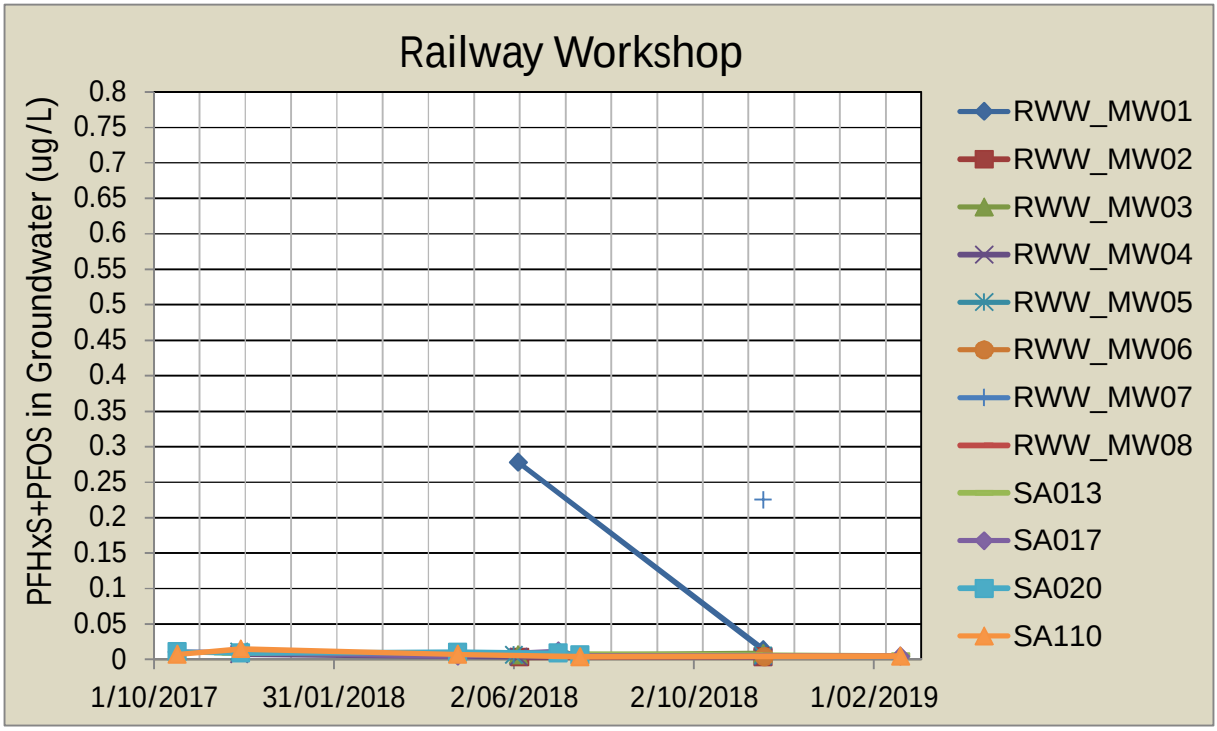


Chart 5 PFHxS+PFOS concentrations in groundwater at Lorim Point Industrial Precinct: October 2017 to February 2019

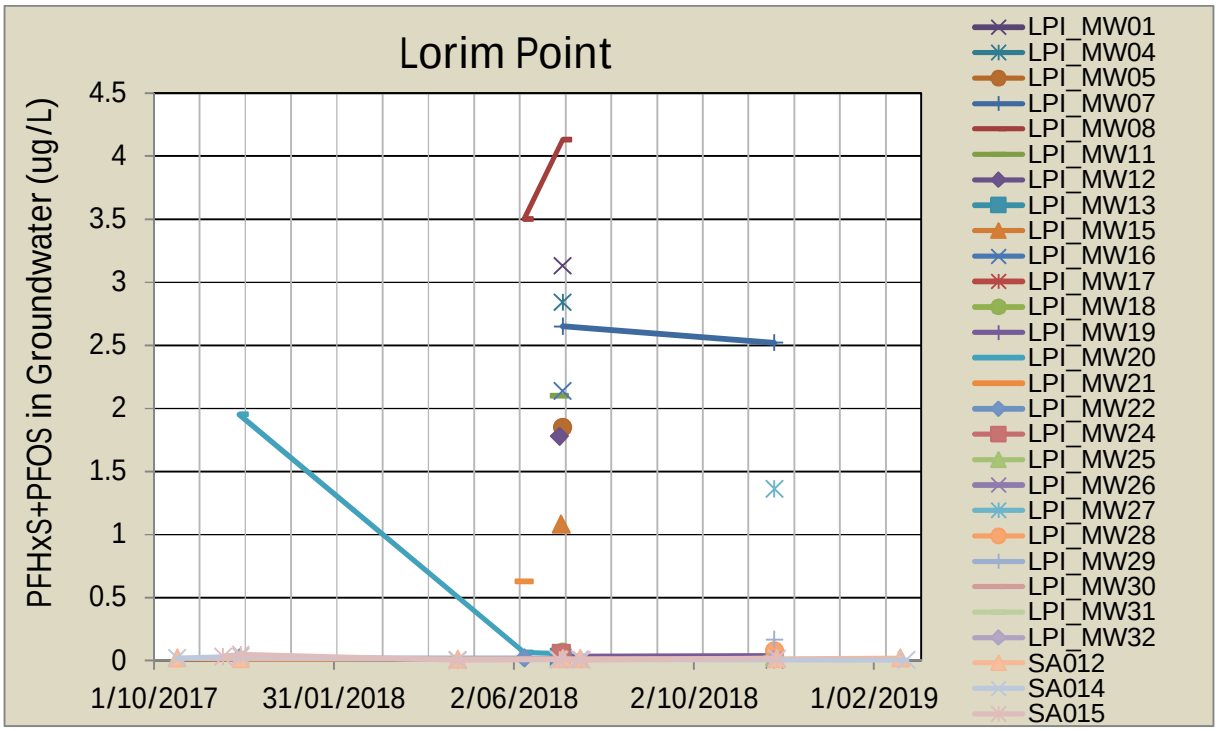


Chart 6 PFHxS+PFOS concentrations in groundwater at Weipa Airport: October 2017 to February 2019

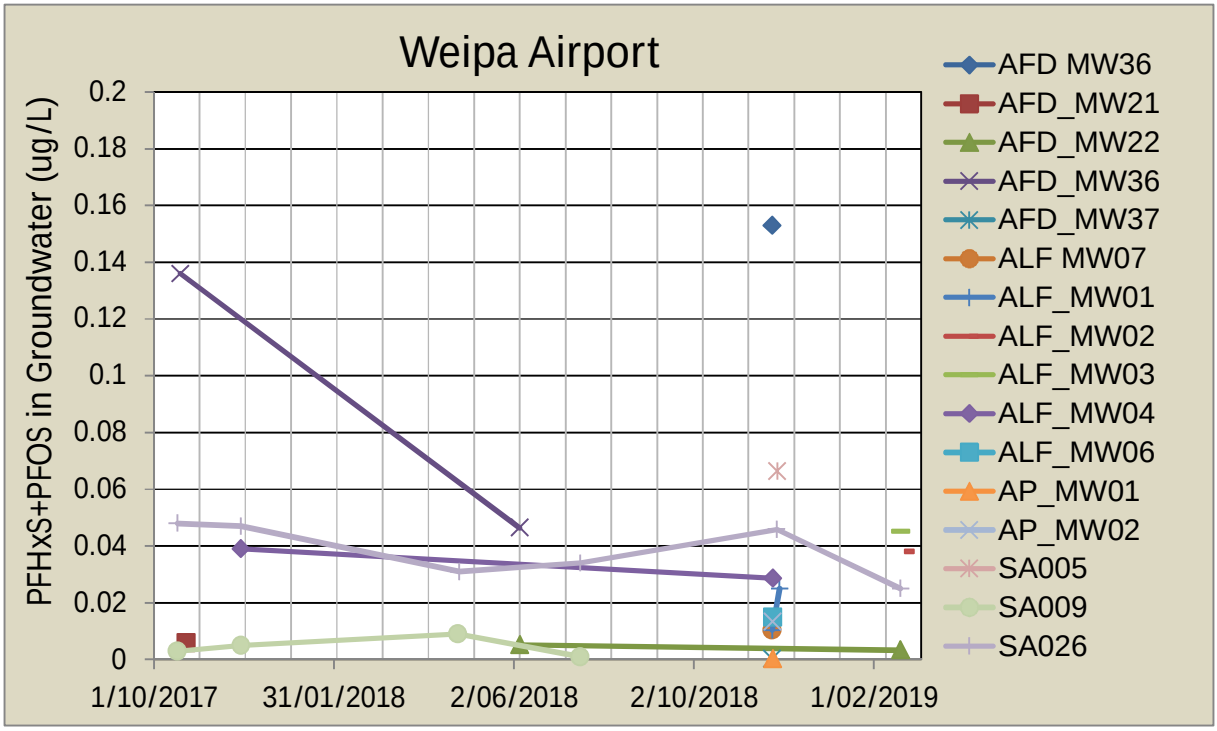


Chart 7 PFHxS+PFOS concentrations in groundwater at East Weipa HEQ: October 2017 to February 2019

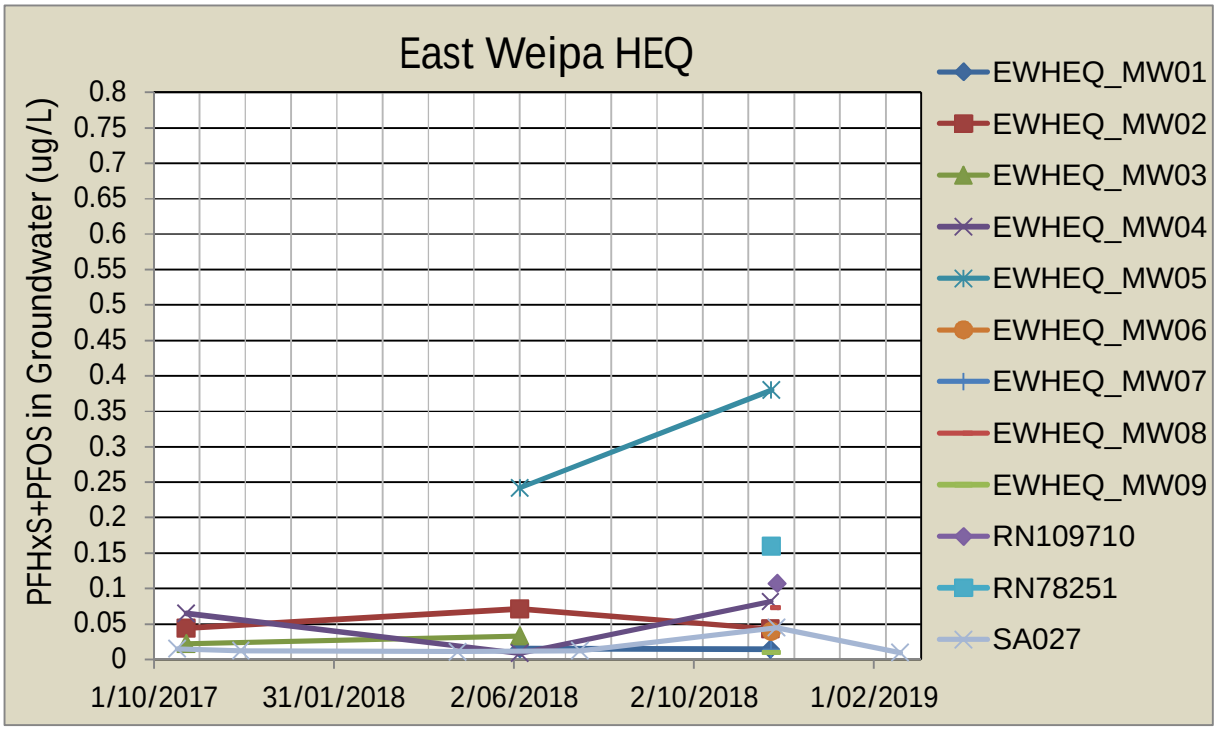
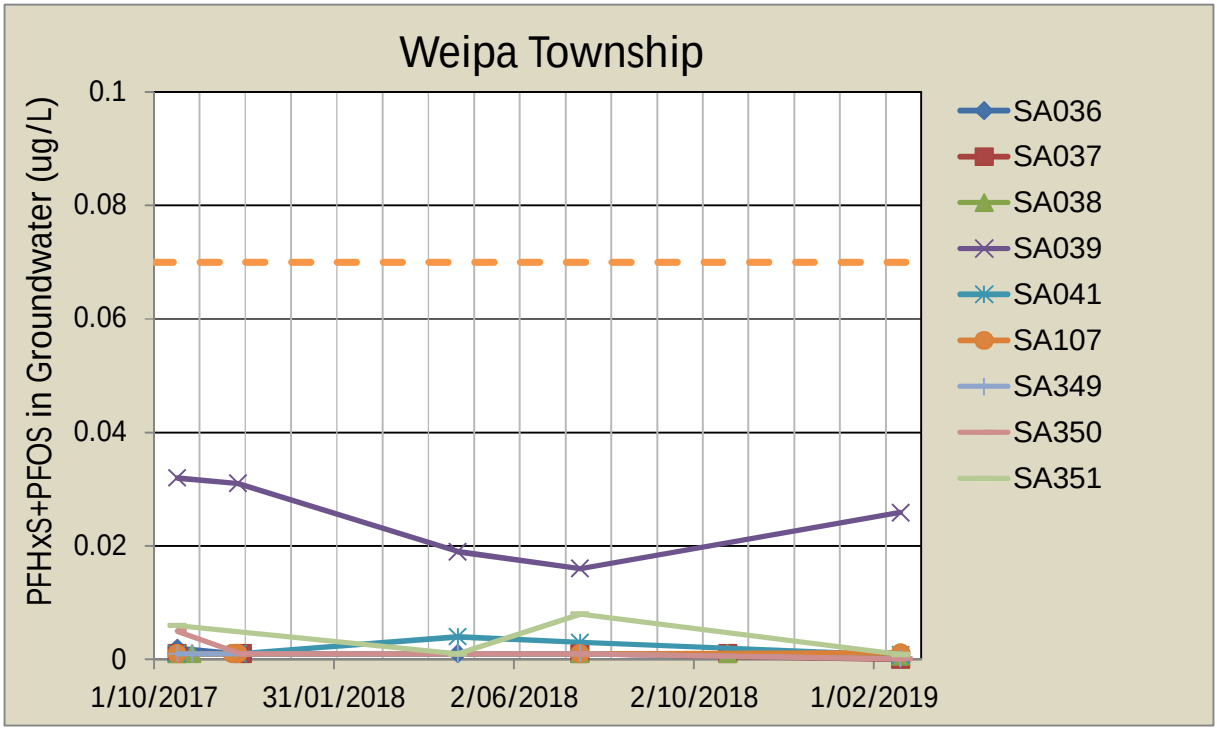


Chart 8 PFHxS+PFOS concentrations in groundwater at Weipa Township: October 2017 to February 2019



8.4.5 Summary

Areas of groundwater impacted by PFAS have been detected at sampling locations hydraulically down-gradient of all six potential primary source areas and also down gradient of Evans Landing landfill (a secondary source area). Fluorotelomers were detected at hydraulically up-gradient and cross-gradient locations at all the potential primary sources areas. The distribution of the different compounds is considered to relate to the historical use of different types of firefighting foams in different areas of the site.

Groundwater samples from Lorim Point had PFAS groundwater concentrations (maximum of 4.1 µg/L sum of PFHxS and PFOS at LPI_MW08 in July 2018) approximately one order of magnitude higher than other six potential primary source areas. The source area with the next highest PFHxS+PFOS concentration was at Evans Landing (0.7 µg/L in ELS_MW18). Groundwater concentrations in at least one monitoring well from each potential primary source area have exceeded the adopted human health drinking water and ecological guideline levels, however the monitoring wells are not used for potable purposes. There were no exceedances of human health guideline levels for groundwater samples from abstraction bores.

The lateral extent of PFHxS+PFOS in groundwater is considered to be suitably characterised at all potential primary source areas based on the risk profile. Some data gaps have been identified for hydraulically down- and cross-gradient locations at Andoom and East Weipa HEQs and the Railway Workshop.

Due to the limited groundwater dataset (typically only one or two rounds of data from the monitoring wells), in most cases there are insufficient data to establish trends in groundwater concentrations and the effect of seasonality. A larger groundwater dataset is available for abstraction bores (up to six rounds of sampling), showing steady concentrations that are below the drinking water guideline level.

8.5 Interpretation of Surface Water and Sediment Analytical Results

For the purposes of this evaluation, concentrations of the different types of PFAS detected during the monitoring events conducted between October 2017 and February 2019 have been used to inform the

assessment of the extent of PFAS. Historical surface analytical data are presented in **Table T15**, **Appendix B**

8.5.1 Embley River- Evans Landing

PFAS was not detected in offshore samples collected in dry and wet seasons (including at high and low tide conditions) in November 2018 and February 2019 indicating that PFAS in soil and groundwater beneath Evans Landing has not adversely affected surface water quality offshore.

PFAS was detected in all six near shore surface water samples in the wet season during both high and low tide conditions in November 2018 and February 2019 but in only one out of six samples collected in the dry season at low tide. PFOS exceeded the adopted ecological IL (99% species protection) in these seven samples. PFOS, PFHxS and PFPeA were the only compounds detected. PFAS concentrations were similar at all three sampling points in the wet season (February 2019). PFAS was not detected in sediment samples collected from the near shore suggesting that sediments in these areas do not act as sinks for PFAS and PFAS predominantly occurs in the aqueous phase. Near shore surface water samples collected in June 2018 (after the wet season) indicated similar concentrations (maximum of 0.0023 µg/L PFHxS+PFOS in EMB/EV/NSB) to those detected during the wet season in February 2019 (maximum of 0.0037 µg/L PFHxS+PFOS in EMB/EV/NSB).

The results suggest the influence of tidal dilution during the wet season is not as strong, possibly due to greater PFAS flux from groundwater and surface water flow. The compounds detected are those with higher mobility.

8.5.2 Embley River- Lorim Point

PFAS was not detected in offshore samples collected in dry and wet seasons (and at high and low tide conditions) indicating that PFAS in soil and groundwater beneath Lorim Point has not adversely affected surface water quality offshore.

PFAS was detected in four near shore surface water samples in the wet season and three near shore surface samples during the dry season. There were detections at all three sampling locations and during both high and low tides. PFOS exceeded the adopted ecological IL for the protection of fresh/marine water species (99% protection) in these seven surface water samples. The highest PFAS concentration (0.35 µg/L PFHxS+PFOS in EMB/LP/NSB_Low) was detected at the Jetty, the closest sampling point to the potential primary source area during the wet season. The results suggest the influence of tidal dilution during the wet season is not as strong, possible due to a higher flux of PFAS migrating from Lorim Point in the wet season, which may be due to increased overland flow which mobilises PFAS in surface soil or a higher rate discharge of contaminated groundwater due to the higher groundwater elevations in the wet season.

PFAS was detected in one sediment sample collected from the same location as the surface water sample with the highest PFAS concentration (EMB/LP/NSB). The sample had a trace concentration of PFOS. The results suggest that sediments in these areas do not act as sinks for PFAS and PFAS predominantly occurs in the aqueous phase.

Near shore surface water samples collected in July 2018 (after the wet season) indicated low concentrations (maximum of 0.0007 µg/L PFHxS+PFOS in EMB/LP/NSB) to those detected during the dry season in November 2018 (maximum of 0.0009 µg/L PFHxS+PFOS in EMB/LP/NSC).

8.5.3 Beening Creek- Weipa Airport

Three locations were sampled along Beening Creek during the dry and wet seasons. PFAS was detected in all three surface water samples collected during the wet season (February 2019). The midstream sample had a slightly higher PFAS concentration (0.007 µg/L PFHxS+PFOS in SW/BEN/MID) compared to the upstream and downstream samples that had concentrations at least seven times lower. The results indicate there are locally higher concentrations in the midstream area. PFAS concentrations are lowest at the downstream sampling location. A trace concentration of PFOS (0.0007 mg/kg) was detected in one of the four sediment samples collected indicating minor impact to this creek. PFOS exceeded the adopted IL for the 99% protection of fresh/marine water species in four of the five surface water samples.

8.5.4 East Weipa HEQ Wash Bay Discharge Outlet

The results indicated PFAS was present at elevated concentrations in surface water (0.3-0.38 µg/L PFHxS+PFOS) and sediment samples (0.01-0.26 mg/kg sum of PFAS) collected from the wash bay in November 2018 and February 2019. The wash bay area is considered to represent a localised source of PFAS. The concentration of PFOS in all four surface water samples exceeded the adopted IL for protection of fresh/marine water species. PFAS concentrations in surface water and sediment are elevated at a sampling position 30 m downstream (0.03-0.05 µg/L PFOS in surface water) indicating PFAS has migrated along this channel. No PFAS impacts were detected in the sediment at a sampling position approximately 200 m downstream, which provides evidence for the extent of PFAS along this channel.

The surface water sample collected from the wash pad in April 2018 (0.05 µg/L PFOS) had a similar concentration to that detected in November 2018 / February 2019. The downstream location was monitored on two occasions in April and July 2018, which recorded concentrations (0.057 to 0.092 µg/L PFOS) higher those reported for November 2018 / February 2019 (0.034 to 0.053 µg/L PFOS).

8.5.5 Andoom HEQ Wash Pad Discharge Outlet

The results indicated PFAS was present at elevated concentrations in surface water (0.30-0.38 µg/L PFOS) and sediment samples (0.03-0.18 mg/kg sum of PFAS) collected from the wash pad and a position approximately 30 m downstream. The concentration of PFOS in all five surface water samples exceeded the adopted IL for protection of fresh/marine water species. The wash pad is considered to represent a localised source of PFAS within the Andoom HEQ area. The surface water sample collected from the wash pad in April 2018 (0.4 µg/L PFOS) had a similar concentration to that detected in November 2018 / February 2019.

8.5.6 Summary

PFAS impacts were detected above the surface water guideline level for the 99% protection of fresh/marine water species at near shore areas along Embley River adjacent to Evans Landing (maximum of 0.004 µg/L PFOS) and Lorim Point (maximum of 0.02 µg/L PFOS) with higher PFAS concentrations generally detected during the wet season (at both high and low tide conditions), which is likely to be related to higher PFAS flux migrating offsite into the near shore environment. There were no exceedances of adopted human health guideline level for recreational use of surface water.

No offshore PFAS impacts were detected in surface water (maximum 0.002 µg/L PFOS). PFAS impacts were detected above the surface water guideline level for the 99% protection of fresh/marine water species in surface water sampling locations collected during dry and wet seasons along Beening Creek.

Surface water samples collected from wash bay/pads at Andoom and East Weipa HEQ had elevated PFAS concentrations that exceeded the surface water guideline level for the 99% protection of fresh water species, and these locations are considered to be localised sources of PFAS. PFAS was detected in surface water and sediment samples at downstream (30 m) sampling locations (located approximately 30 m distance), at lower concentrations compared to the washpad/bay outlets. This indicates the extent of the surface water and sediment impacts may extend beyond the locations of the downstream sampling points. There were no exceedances of adopted human health for recreational use of surface water.

9.0 Conceptual Site Model

9.1 Introduction

9.1.1 Purpose

The purpose of the CSM is to provide an understanding of the nature and extent of contamination impacts and the migration mechanisms, and the exposure pathways by which identified receptors may be exposed to contamination from the investigation areas, and to serve as a framework to assess risks to human health and ecological receptors. The CSM also assists in identifying uncertainties and data gaps. A preliminary CSM was developed as part of the PSI and refined with the interim risk assessment (AECOM, 2018b). The CSM has been updated based on the findings of this DSI.

9.1.2 Definition of source-pathway-receptor linkages

In accordance with national guidance on assessment of contamination (NEPM, 2013), potential risks to receptors are evaluated based on three components:

- **Source**: A potentially hazardous substance that has been released into the environment
- **Receptors**: A person, ecosystem or ecological member potentially at risk of experiencing an adverse response following exposure to the source or derivatives of the source
- **Pathway**: A mechanism by which receptors can become exposed to the source or derivatives of the source.

If all three components are present at an exposure scenario, the source-pathway-receptor linkage is considered complete and a receptor is exposed to risk. However, if one of these three is missing there is no risk.

9.2 Sources

The main source areas of PFAS contamination in the Andoom and Weipa areas are summarised below.

9.2.1 Primary Sources

The following activities on the site are considered to have resulted in PFAS impacts to soil, sediment, surface water and/or groundwater:

- Historical firefighting training using AFFF containing PFAS at the F&R area at Lorim Point
- Historical firefighting training using AFFF containing PFAS at Evans Landing area
- Historical firefighting training using AFFF containing PFAS at Weipa Airport
- Discharge of AFFF containing PFAS at heavy equipment workshops at Andoom and East Weipa
- Discharge of AFFF containing PFAS at Railway Workshop
- Inadvertent discharge of AFFF containing PFAS in areas around the Andoom HEQ
- Discharge of AFFF in response to emergency response
- Discharge of AFFF at Civil Workshop, Lorim Point Fuel Depot and Andoom Service Bay

There is the potential for precursor compounds to be present in some areas in addition to the known PFAS. Some of these precursor compounds have the potential to transform into end products such as PFOS and PFOA.

9.2.2 Secondary Sources

The following features on the site are considered to potentially lead to PFAS impacts:

- Concrete infrastructure that has been in contact with AFFF
- Surface soil where AFFF was discharged to surface

- Unsaturated zone soil beneath potential source zones
- Sediment and soil along drainage channels
- Evans Landing Landfill
- Other landfills, Andoom HEQ, Mission River Bridge, Trunding, Tonkin Road, Denman's Domestic, Area G&X and Area Y, C North Extension, Trunding Creek, C-South Industrial Waste, Weipa Airport, Napranum, Area Q)
- Tailing Storage Facility (Andoom, East Weipa)
- Lorim Point Sewage Treatment Plant, Napranum Sewage Ponds
- Herring Oil Slot
- East Weipa Bioremediation Pad.

9.3 Migration Mechanisms

The mechanisms which may have contributed to the migration of PFAS from within the site include:

- Discharge of AFFF containing PFAS to ground surface or leakage from storage infrastructure
- Spilling of AFFF containing PFAS to ground surface during filling and decanting operations
- Sorption of PFAS to soil in areas where AFFFs were historically used
- Localised dispersion of firefighting foams with wind during historical application
- Surface water run-off containing PFAS flowing into surface water and off-Site migration within the drainage system
- Leaching of PFAS from soil and infiltration to groundwater in areas where AFFFs were historically used
- Lateral and vertical migration of PFAS in groundwater under the influence of groundwater flow and PFAS dispersion
- Sorption of PFAS to soil below the groundwater table during migration with groundwater. Sorption to soil slows down the migration of PFAS but sorbed PFAS may continue to diffuse back into groundwater and act as a secondary source, if conditions are suitable
- Excavation of soil containing PFAS and relocation
- Leaching of PFAS from concrete structures and infiltration to groundwater
- Leaching of PFAS in buried waste at the landfill
- Transport of surface water and sediment containing PFAS into Andoom and Benning Creeks and Embley and Mission Rivers.
- Irrigation of groundwater containing PFAS across the investigation areas for dust suppression.

9.4 Exposure Pathways:

The following potential exposure pathways have been identified for the investigation areas and adjoining areas:

- Persons incidentally ingesting PFAS impacted soil
- Persons in direct contact with PFAS impacted surface water during recreational activities
- Persons drinking or using PFAS impacted abstracted groundwater from abstraction bores
- Persons consuming aquatic biota from PFAS impacted surface water
- Ecological receptors in direct contact with PFAS impacted soil, sediment and surface water.

9.5 Receptors

The following potential receptors have been identified:

- Personnel who work at the site
- Recreational users of the surface water (Embley River, Mission River)
- Intrusive (i.e. involved in soil excavation) maintenance workers who may conduct infrequent maintenance activities at the site and come into contact with impacted soil
- Users of abstracted groundwater
- Human consumers of impacted aquatic biota
- The terrestrial ecosystem following potential off-site irrigation using water or overland run-off
- The aquatic ecosystem of the Embley River, Mission River, Andoom Creek and Beening Creek.

9.6 Assessment of Exposure Pathways

An assessment of the exposure pathways for Mission River and Embley River catchments are presented in **Table 46** and **Table 47**.

Table 46 Mission River catchment CSM

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
Andoom Heavy Equipment Workshop (AHEQ) identified soil source and elevated concentrations in down gradient groundwater. PFAS has been released to the environment from this facility during annual servicing of fire suppression systems on HME during the period 1997 to 2017 PFAS can soak into soil and / or infrastructure from where it can be eroded as sediment or leached by rainwater or flood water and migrate to groundwater or dissolved in surface water runoff and potentially transported to affect other media.	PFAS in shallow soil (<2.0 m)	Water erosion Excavation and re-location of soil during construction activities	Human health: Incidental ingestion of soil on-Site	Personnel who work at the site	Incomplete (Soil PFAS concentrations below adopted human health (HH) guidelines)
			Human health: Direct contact with soil on-Site	Personnel who work at the site	Incomplete (Soil PFAS concentrations below adopted HH guidelines)
			Ecological	On-Site ecosystem	Incomplete (Soil PFAS concentrations below adopted ecological guidelines)
	PFAS in groundwater PFAS in soil leachate PFAS in potable water	Groundwater transport in the aquifer followed by extraction and use for recreational and domestic uses and irrigation	Human health: Direct ingestion of groundwater (on- and off-Site)	Personnel who work at the site, residential users of abstracted water	Incomplete (Potable water PFAS concentrations below adopted HH guidelines. Groundwater (GW) and leachate PFAS concentrations above HH guidelines, but there is no identified linkage between impacted GW, leachate and human consumption).
			Human health: Incidental ingestion of groundwater (on- and off-Site)	Personnel who work at the site, residential users of abstracted water	Incomplete (see above)
			Human health: Direct contact with groundwater (on- and off-Site)	Personnel who work at the site, residential users of abstracted water	Incomplete (see above)
	PFAS in surface water	Surface water transport, discharging to Mission River	Human health: Incidental ingestion of surface water (on- and off-site)	Recreational	Incomplete (SW PFAS concentrations below adopted HH guidelines)

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
			Human health: Direct contact with surface water (on- and off-Site)	Recreational	Incomplete (SW PFAS concentrations below adopted HH guidelines)
			Ecological (on and off-Site)	Ecosystem (on and off-Site)	Complete (SW PFAS concentrations in Andoom Creek above ecological guidelines)
	PFAS in sediment	Dispersion via surface water or via drain maintenance activities.	Human health: Incidental ingestion of sediment on-Site.	Personnel who work at the site, residential	Potentially Complete (Anecdotal evidence suggests sediment from the drainage system is potentially impacted by PFAS)
			Human health: Direct contact of sediment on-Site.	Personnel who work at the site, residential	Potentially Complete (see above)
			Ecological (on- and off-Site).	Ecosystem (on- and off-Site)	On-site Potentially Complete (see above) Off-site Incomplete (Sediment PFAS concentrations below adopted ecological guidelines and <LOR)
			Human health: Incidental ingestion of sediment off-Site, impacted by surface water or groundwater (extracted via bore).	Residential	Incomplete (Sediment PFAS concentrations below adopted HH guidelines and <LOR)

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
			Human health: Direct contact of sediment on- and off-Site impacted by groundwater (extracted via bore) or surface water	Personnel who work at the site, residential	Potentially Complete. (Anecdotal evidence suggest PFAS in sediment on-site, and PFAS concentrations in groundwater are above adopted HH guidelines)
	Terrestrial biota	Harvesting	Human health: Ingestion of terrestrial organisms (including fruit and vegetables, chicken eggs)	Residential	Incomplete (Potable water PFAS concentrations below adopted HH guidelines. GW PFAS concentrations are above HH guidelines, but there is no identified linkage between impacted GW and human consumption).
			Ecological (on- and off-Site).	Ecosystem (on- and off-Site)	Incomplete (PFAS concentrations in soil below eco guidelines)
	Aquatic biota	Harvesting	Human health: Ingestion of aquatic organisms (including fish and yabbies, shrimps and mussels)	Residential, recreational	Incomplete (PFAS concentrations in biota below adopted HH guidelines)
			Ecological (off-Site).	Ecosystem (off-Site)	Incomplete (PFAS concentrations below adopted ecological guidelines)

Table 47 Embley River CSM

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
Evans Landing, Evans Landing Landfill, Railway Workshop, Lorim Point Industrial Precinct, Weipa Airport and East Weipa HEQ identified PFAS source and elevated concentrations in downgradient groundwater. On-Site areas where fire-fighting retardants /suppression foams have been discharged or spilt to	PFAS in shallow soil (<2.0 m)	Water erosion Excavation and re-location of soil during construction activities	Human health: Incidental ingestion of soil on-Site	Commercial/industrial	Incomplete (Soil PFAS concentrations below adopted HH guidelines)
			Human health: Direct contact with soil on-Site	Commercial/industrial	Incomplete (Soil PFAS concentrations below adopted HH guidelines)
			Ecological	On-Site ecosystem	Complete for Lorim Point and East Weipa HEQ. (Soil PFAS concentrations above adopted Eco guidelines)

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
the environment PFAS can soak into soil and / or infrastructure from where it can be eroded as sediment or leached by rainwater or flood water and migrate to groundwater, or dissolved in surface water runoff and potentially transported to affect other media.	PFAS in groundwater PFAS in soil leachate PFAS in potable water	Groundwater transport in aquifer followed by extraction and use for recreational and domestic uses and irrigation	Human health: Direct ingestion of groundwater (on- and off-Site)	Commercial/industrial, residential	Incomplete (Potable water PFAS concentrations below adopted HH guidelines and abstraction bores SA014 and SA015 located nearby the GW plume at Lorim Point have been excluded from the potable water network. GW and leachate PFAS concentrations are above HH guidelines, but there is no identified linkage between impacted GW and human consumption.
			Human health: Incidental ingestion of groundwater (on- and off-Site)	Commercial/industrial, residential	Incomplete (see above)
			Human health: Direct contact of groundwater (on- and off-Site)	Commercial/industrial, residential	Incomplete (see above)
	PFAS in surface water	Surface water transport, discharging to Embley River	Human health: Incidental ingestion of surface water (on- and off-Site)	Recreational	Incomplete (SW PFAS concentrations below HH guidelines)

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
			Human health: Direct contact with surface water (on- and off-Site)	Recreational, ecosystem	Incomplete (SW PFAS concentrations below HH guidelines)
			Ecological (on and off-Site)	Ecosystem (on and off-Site)	Complete (SW PFAS concentrations above adopted ecological guidelines)
		Infiltration to groundwater followed by extraction and use for drinking water, recreational uses and irrigation.	Human health: Direct contact with groundwater (on- and off-Site).	Commercial/industrial, residential	Incomplete (Potable water PFAS concentrations below adopted HH guidelines and abstraction bores SA014 and SA015 located nearby the GW plume at Lorim Point have been excluded from the potable water network. GW PFAS concentrations are above HH guidelines, but there is no identified linkage between impacted GW and human consumption).

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
	PFAS in sediment	Dispersion via surface water or via drain maintenance activities.	Human health: Incidental ingestion of sediment on-Site.	Commercial/industrial	Potentially Complete (Anecdotal evidence suggests sediment from the drainage system is potentially impacted by PFAS).
			Human health: Direct contact of sediment on-Site.	Commercial/industrial	Potentially Complete (see above)
			Ecological (on- and off-Site).	Ecosystem (on- and off-Site)	On-site Potentially Complete (see above) Off-site Incomplete (Sediment PFAS concentrations below adopted Eco guidelines and <LOR)
			Human health: Incidental ingestion of sediment off-Site, impacted by surface water or groundwater (extracted via bore).	Residential (off-Site)	Incomplete (Off-Site sediment PFAS concentrations below adopted HH guidelines and <LOR)
			Human health: Direct contact of sediment on- and off-Site impacted by groundwater (extracted via bore) or surface water	Commercial/industrial, residential	Potentially Complete. (Anecdotal evidence suggest PFAS in sediment on-site, and PFAS concentrations in groundwater are above adopted HH guidelines)

Primary source area	Source media	Transport mechanisms	Exposure pathways	Exposed population characterisation / receptor	Linkages
	Terrestrial biota	Harvesting	Human health: Ingestion of terrestrial organisms (including fruit and vegetables, chicken eggs)	Residential (off-site)	Incomplete (Potable water PFAS concentrations below adopted HH guidelines. GW PFAS concentrations are above HH guidelines, but there is no identified linkage between impacted GW and human consumption).
			Ecological (on-Site).	Ecosystem (on -Site)	Complete (PFAS concentrations in on-Site soil are above eco guidelines)
	Aquatic biota	Harvesting	Human health: Ingestion of aquatic organisms (including fish and yabbies, shrimps and mussels)	Residential, recreational	Incomplete (PFAS concentrations in aquatic biota are below adopted HH guidelines)
			Ecological (off-Site).	Ecosystem (off-Site)	Incomplete (PFAS concentrations in aquatic biota are below adopted eco guidelines)

10.0 Review of Environmental Values and Suggested Management Approach

10.1 Review of Environmental Values

The key conclusions of the environmental investigation relevant to the environmental values as specified under the EPP Water (2009) are presented in **Table 48**. In summary, only one of the environmental values identified in the Notice are considered to be impacted by the presence of PFAS in environmental media at the Site.

Table 48 Review of Environmental Values

Environmental Value	Conclusions of the Environmental Investigation
a) for slightly disturbed waters – the biological integrity of an aquatic system that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators	The CSM has identified the potential for aquatic receptors to be exposed to PFAS in surface water at concentrations greater than the adopted screening value. This is based on the exceedance of the NEMP (HEPA, 2018) interim guideline values for 99% protection of marine water species (high conservation systems) in 14 of the 24 near shore surface water samples collected in November 2018 and February 2019.
b) for waters that may be producing aquatic food for human consumption – the suitability of the water for producing the food for human consumption	Based on the findings of the risk assessments on samples of surface water, sediment and biota from the receiving environment, it is concluded that there is negligible risk to human and ecological health from the consumption of aquatic biota and environmental values relating to aquatic food consumption and aquaculture.
c) for waters that may be used for recreation or aesthetic purposes, the suitability of the water for- d) primary recreational use' or (i) secondary recreational use; or (ii) visual recreational use.	Based on the findings of the risk assessments, which did not identify exceedances of recreational guideline values in any of the 62 surface water samples collected from the receiving environment, it is concluded that surface water quality is suitable for recreational use.
e) for waters that may be used for drinking water – the suitability of the water for supply as drinking water	Based on the findings of the risk assessments, which have not identified exceedances of drinking water guidelines for groundwater used for potable purposes from all 22 water supply wells in the shallow aquifer in the period October 2017 to February 2019, it is concluded that the water from these bores is currently suitable for drinking water purposes. Groundwater used for potable water supply from the deeper artesian aquifer has not been investigated as this was considered less likely to be impacted.
f) for waters that may be used for industrial purposes – the suitability of the water for industrial use	Shallow abstraction bores used for industrial purposes in the Andoom area have not been sampled. As all seven bores are located hydraulically up-gradient (to the north) of the Andoom HEQ, it is considered unlikely that groundwater from these bores have PFAS concentrations exceeding human health guidelines. This is based on the extent of sum of PFHxS and PFOS reported which indicated the area of elevated sum of PFHxS and PFOS concentrations are located to the south and southwest of the workshop. Sampling of three of the 21 shallow abstraction bores used for industrial purposes in the East Weipa area, detected PFAS concentration at concentrations below human health guidelines

Environmental Value	Conclusions of the Environmental Investigation
	levels (recreational water). All other abstraction bores are located hydraulically up or cross-gradient of potential primary source areas. Recreational water guidelines are considered appropriate to assess the suitability of water used for industrial purposes for the following reasons: • There are no screening values available to assess the impacts of PFAS on industrial water • PFAS would be unlikely to cause fouling, corrosion or other similar effects on industrial equipment • Humans may be incidentally exposed to water during industrial use. The recreational water criteria in the NEMP are based on ingestion of 200 mL per day for a lifetime, which is considered to be significantly higher exposure than may occur during industrial use of water. Therefore the recreational water criteria are conservative to adopt as screening values for this environmental value. Based on non-exceedance of recreational water guidelines for groundwater abstracted from bores for industrial purposes, and hydraulically up- and cross-gradient locations, it is concluded that the water from these bores is currently suitable for industrial purposes. Groundwater used for industrial purposes from the deeper artesian aquifer has not been investigated as this was considered less likely to be impacted.
g) the cultural and spiritual values of the water.	It is recognised that water resources have important cultural and spiritual values for the indigenous people of Australia. The findings of the risk assessments and investigation indicate negligible impact on the cultural and spiritual values of the water based on the following indicators (as identified in ANZG, 2018[5]): • The risk assessments in the reports indicate the water quality is safe for drinking and the water is safe for sourcing food. • 'Water Country' is considered healthy. • Water quality is safe for recreational and ceremonial purposes. • Water quality is suitable to support the economic wellbeing of indigenous people.

Further consideration of the risk to aquatic ecosystems is presented below.

The CSM identified the potential for complete exposure linkages for PFAS to impact aquatic and terrestrial receptors. This was based on the selection of the surface water PFAS assessment criteria as specified in current guidance, which is discussed below.

For the assessment of estuarine water, ANZECC (2000) identifies that the lower of marine or freshwater criteria should be adopted. While the available scientific research indicates that PFAS may have lower toxicity in marine water compared to freshwater, there are fewer data available and so at this time, the freshwater screening values have been adopted as interim values for the assessment of marine ecosystems. The HEPA and DoEE (2018) PFAS NEMP advises that freshwater values are to

[5] Australia and New Zealand Guidelines, 2018, http://waterquality.gov.au/anz-guidelines

be used on an interim basis until final marine guideline values can be set, using the nationally-agreed process under the Australian and New Zealand Guidelines for Fresh and Marine Water Guidelines. The water quality guidelines advise that the 99% level of species protection be used for chemicals that bioaccumulate and biomagnify in wildlife when assessing 'slightly to moderately disturbed' systems where local data are lacking on bioaccumulation effects.

It is recognised that exceedance of the HEPA and DoEE (2018) guideline level for PFAS in surface water (i.e. the 99% species protection level) does not necessarily mean an unacceptable risk is present and environmental harm is being caused. Exceedance of the NEMP (HEPA and DoEE, 2018) guideline levels are therefore used to guide whether further assessment is required.

It is noted that recently published ecological research (reported in Batley et al (2018) *Application of revised methodologies for default guideline value derivations: PFOS in freshwater*, presented at the Society of Environmental Toxicology and Chemistry (SETAC) scientific conference in November 2018) suggests a draft revised 99% species protection criterion of 0.051 µg/L for PFOS. AECOM understands that this criterion is currently subject to further review to include additional data from recently published scientific research. Notwithstanding this limitation, it is considered that this draft guideline value can be used to assess the potential significance of the surface water concentrations present at the Site.

An assessment of all PFOS concentrations in surface water compared to the Batley et al (2018) screening level is summarised in **Table 49**.

Table 49 Assessment of Surface Water Concentrations

Closest Primary Source Area	Location	No. of Samples	Maximum PFOS (µg/L)	No. of exceedances of Batley et al (2018) guideline (0.051 µg/L PFOS)	Maximum PFOS (mg/kg) in sediment
Andoom HEQ	Andoom Creek	4	0.0217	0	None
	Andoom Washpad / Wash Tower	8	0.038	0	0.0018
	Andoom creeks / swamps (Sunrise Creek, Botchett and Saleng Tea Tree Swamps)	3	<0.0003	0	None
Evans Landing	Embley River (near shore)	15	0.0039	0	<0.0002
	Embley River (off shore)	12	<0.0003	0	None
	Lakes (McLeod, Patricia)	2	<0.0003	0	None
	Trunding Creek	2	0.0015	0	None
Lorim Point	Embley River (near shore)	15	0.019	0	0.0003
	Embley River (off shore)	12	<0.0003	0	None
Weipa Airport	Beening Creek	8	0.004	0	<0.0002
East Weipa HEQ	East Weipa HEQ Washpad	7	0.0614	2	0.0075
	East Weipa creeks (Mission River, Pappan, Marmoss)	7	0.001	0	None

As shown in **Table 49**, with the exception of one location, all PFOS concentrations are below the Batley et al (2018) screening level. The only surface water samples that exceeded the Batley et al (2018) screening level are located at the East Weipa HEQ washpad. It is noted that this sampling location is actually a discharge point for workshop operations and is not representative of a natural aquatic ecosystem (the nearest water feature is the Beening Creek located 1.7 km to the southeast). Runoff from the discharge has the potential to migrate to natural ecological receiving environments such as Beening Creek. Therefore, environmental values are not considered relevant at the discharge point of the East Weipa HEQ.

Based on the available information it is concluded that while some PFOS concentrations exceeding the 99% species protection level have been reported in water, risks are considered likely to be acceptable and further assessment is not considered warranted at this time because:

- The available scientific research indicates that PFOS may have lower toxicity in marine water compared to freshwater.
- With the exception of the East Weipa HEQ washpad, the concentrations of PFOS reported in surface water did not exceed the Batley et al (2018) screening level, which is based on the same data as the HEPA (2018) freshwater screening level excluding data for plants. The available data indicate that plants are significantly less sensitive to PFOS compared to other organisms assessed and therefore resulted in a bi-modal species sensitivity distribution which Batley et al (2018) concluded biased the 99% species protection level low.
- The East Weipa HEQ washpad sampling location is not representative of conditions in the natural aquatic ecosystem.

If marine ecosystem species protection criteria or revised freshwater ecosystem species protection criteria are published in future revisions to the NEMP, then this assessment should be revisited to confirm that these conclusions remain valid.

10.2 Suggested Management Approach

The suggested management approach for surface water, sediment, groundwater and soil at the site is described in the following subsections.

10.2.1 Surface Water and Sediment

Although current PFAS concentrations in surface water are not considered to adversely impact environmental values, due to the proximity of PFAS impacted groundwater adjacent to Embley River, and Beening Creek, it is recommended that surface water monitoring at the near shore sampling locations along Embley River and Beening Creek sampling locations is conducted biannually (representative of dry and wet seasons) for a period of approximately three years to allow potential changes in PFAS concentrations (and impact on aquatic ecosystems) to be assessed.

It is noted that there is limited information on longer term trends and the effect of seasonality and additional sampling would address these data gaps. The seasonal changes to PFAS concentrations in the surface water can also be used to inform the potential impact on aquatic biota tissue PFAS concentrations for biota residing in the rivers / creeks. For example, if surface water concentrations do not increase between dry and wet seasons, it would be expected that aquatic biota PFAS concentrations would also not increase significantly and the risk to human health from consumption of the biota would remain low. It is noted that based on the current margin of safety in comparison to the FSANZ (2017) trigger values, minor increases in environmental PFAS concentrations from dry to wet season may not result in significant variation in aquatic biota tissue PFAS concentrations or a change in the overall risk profile.

It is recommended that co-located sediment samples (with surface water samples) are collected annually at the end of the wet season to provide additional monitoring data to allow assessment of the potential for changes to PFAS concentration in the aquatic environment and the risk to biota.

10.2.2 Groundwater

Groundwater remediation is not considered to be necessary at the Site at the present time for the following reasons:

- the use of the primary sources of PFAS contamination (AFFF containing PFHxS+PFOS) are being phased out;
- the extent of the PFAS impacted areas have been assessed;
- NEMP drinking water guideline levels were not exceeded in potable abstraction bores;
- NEMP recreational water guideline levels were not exceeded in abstraction bores used for industrial purposes (where sampled); and
- adverse effects on the environmental values and environmental harm relating to groundwater were not identified.

It is recommended that the PFAS contamination is managed by conducting monitoring of the groundwater, targeting identified source areas, areas down-gradient of these source areas and at abstraction bores. The purpose of the monitoring would be to provide information on the current extent of PFAS in groundwater and to enable further evaluation if the distribution has changed.

It is recommended that groundwater monitoring of selected abstraction bores and groundwater monitoring wells is conducted biannually, representative of dry and wet seasons for a period of three years to allow potential changes in PFAS concentrations and impact on environmental values to be assessed. It is suggested that those potable bores close to areas with elevated PFAS concentrations in groundwater (i.e. SA110, SA012, SA014, SA015, SA026) are monitored at a higher frequency (quarterly) to provide data for regular assessment.

10.2.3 Soil

The soil investigations conducted in 2017 and 2018 have indicated soil contains detectable PFAS in discrete locations at Andoom HEQ, Lorim Point and East Weipa HEQ. Although none of the soil samples exceeded NEMP human health guideline levels for industrial landuse, the PFAS in the soil is readily leachable and represents a secondary source of PFAS to groundwater and surface water. There is limited soil data as the investigations were not able to target potential areas where AFFF may have been released to ground, as there were limited records and anecdotal information available on the historical discharge of AFFF. As the investigations have not identified large areas of soil affected by PFAS, soil remediation is not recommended at the present time.

11.0 Conclusions

The report is considered to meet the overall objective of the DSI, which is to understand the nature and extent of the identified PFAS impact and to address Requirement 8 of the DES *Notice to conduct or commission an environmental evaluation*, dated 7 September 2018 (the 'Notice') Reference 101/0008738, CR84931, STAT1304, The following conclusions are made addressing the requirements as described in the Notice.

Extent of PFAS in Soil

The soil investigations in 2017 and 2018 have identified the presence of areas of soil with locally higher PFAS concentrations (above ecological guideline levels for industrial landuse) in shallow soil at three of the potential primary source areas (Andoom HEQ, Lorim Point and East Weipa HEQ). The soil samples were collected from locations across the open areas at these facilities. PFAS concentrations in 11% of the samples exceeded the ecological guideline level for industrial landuse (maximum of 2.5 mg/kg in a soil sample from Lorim Point), however, none of the soil sample concentrations exceeded human health guidelines levels for industrial landuse.

The results indicate localised discrete areas of PFAS are present in soil at these three facilities. Results indicate the higher concentrations of PFAS were detected in near surface soil. Relatively minor PFAS impacts (close to or below laboratory limit of reporting) were detected in soil samples from across Weipa Airport and the Railway Workshop. The results in these source areas are not considered to be consistent with large sources of PFAS in soil. Information on the exact areas where AFFF was discharged to ground was not recorded, therefore the sampling locations could not be targeted on these areas.

Extent of PFAS in Groundwater

Areas of groundwater impacted by PFAS have been detected at sampling locations hydraulically down-gradient of all six potential primary source areas and also down gradient of Evans Landing landfill (a secondary source area). Fluorotelomers were detected at hydraulically up-gradient and cross-gradient locations at all the potential primary sources areas. The distribution of the different compounds is considered to relate to the historical use of different types of firefighting foams in different areas of the site.

Groundwater samples from Lorim Point had PFAS groundwater concentrations (maximum of 4.1 µg/L sum of perfluorohexanesulfonic acid (PFHxS) and perfluorooctanesulfonic acid (PFOS) at LPI_MW08 in July 2018) approximately one order of magnitude higher than the other six potential primary source areas. The source area with the next highest sum of PFHxS and PFOS concentration was Evans Landing (0.7 µg/L in ELS_MW18). Groundwater concentrations in at least one monitoring well from each potential primary source area have exceeded the adopted human health drinking water and ecological guideline levels, however the monitoring wells are not used for potable purposes. There were no exceedances of human health guideline levels for groundwater samples from abstraction bores.

The lateral extent of sum of PFHxS and PFOS in groundwater is considered to be suitably characterised at all potential primary source areas based on the risk profile. Some data gaps have been identified for hydraulically down- and cross-gradient locations at Andoom and East Weipa HEQs and the Railway Workshop.

Due to the limited groundwater dataset (typically only one or two rounds of data from the monitoring wells, which were first sampled in 2018), in most cases there are insufficient data to establish trends in groundwater concentrations and the effect of seasonality. A larger groundwater dataset is available for potable abstraction bores[6] (up to six rounds of sampling), showing steady concentrations that are below the drinking water guideline level.

[6] Water supply bores have been monitored more frequently since 2017 because, consistent with the National Environmental Management Plan (HEPA and DoEE, 2018), greater priority has been placed at this stage of the program for the protection of human health since groundwater beneath the Site is used supply potable/drinking water to the Site and the Weipa Township/community.

Extent of PFAS in Surface Water and Sediment

PFAS impacts were detected above the surface water guideline level for the 99% protection of fresh/marine water species at near shore areas along Embley River adjacent to Evans Landing (maximum of 0.004 µg/L PFOS) and Lorim Point (maximum of 0.02 µg/L PFOS) with higher PFAS concentrations detected during the wet season, which is likely to be related to higher PFAS flux migrating offsite into the near shore environment. There were no exceedances of adopted human health guideline level for recreational use of surface water.

No offshore PFAS impacts were detected in surface water. PFAS impacts (maximum 0.002 µg/L PFOS) were detected above the surface water guideline level for the 99% protection of fresh/marine water species in surface water sampling locations collected during dry and wet seasons along Beening Creek.

Surface water and sediment samples collected from wash bay/pads at Andoom and East Weipa HEQ had elevated PFAS concentrations that exceeded the surface water guideline level for the 99% protection of fresh water species, and these locations are considered to be localised sources of PFAS. PFAS was detected in downstream sampling locations (located approximately 30 m distance), at lower concentrations compared to the washpad/bay outlets. This indicates the extent of the surface water and sediment impacts may extend beyond the locations of the downstream sampling points. There were no exceedances of adopted human health for recreational use of surface water.

Conceptual Site Model

Based on the results of this investigation, the conceptual site models for the Mission River and Embley River catchments initially developed in the PSI (Golder 2018a) and updated in the Interim Risk Assessment (AECOM, 2018b) have been refined. This DSI has obtained additional characterisation data for all six potential primary source areas and one secondary source area identified in the PSI. The detection of PFAS in soil, groundwater, surface water and sediment at all the areas targeted in this investigation indicates that all seven areas are local sources of PFAS.

Potential migration mechanisms for PFAS were identified to be through infiltration to groundwater and dispersion via groundwater flow, overland surface water run-off and surface water and sediment transport in creeks and rivers. Other important potential migration pathways include leaching of soil impacted by PFAS, excavation and relocation of soil impacted with PFAS and leaching of buried waste in landfills.

The report has identified that seasonal changes at the site appears to affect the distribution of contamination in near shore surface water, with relative higher PFAS concentration detected during the wet season. It is speculated that during the wet season, higher rainfall and associated surface water runoff could potentially mobilise PFAS contaminants in near-surface soils with run-off into drainage channels, creeks and rivers.

The potential receptors identified through this investigation include personnel who work at the site, users of abstracted groundwater, recreational users of nearby surface water bodies, intrusive maintenance workers, the terrestrial ecosystem and the aquatic ecosystems of the creeks and rivers and potential consumers of impacted aquatic biota within the surface water receptors.

Potentially complete source-pathway-receptor linkages have been identified for the migration of PFAS to impact ecological receptors in the investigation areas and in in adjoining waterways:

- For the Mission River catchment (Andoom HEQ), a potentially complete exposure pathway has been identified for:
    - aquatic receptors in Andoom Creek to be exposed to via PFAS in surface water.
- For the Embley River catchment (Lorim Point, Evans Landing, Weipa Airport and East Weipa HEQ), complete exposure pathways have been identified for:
    - terrestrial receptors (e.g. invertebrates) to be exposed to PFAS in soil and by harvesting
    - aquatic receptors in the Embley River to be exposed to PFAS in surface water.

Environmental Values

Based on the available information, it is concluded that there is no adverse impact on the environmental values. This is based on the following:

- Risks to ecological receptors are considered likely to be acceptable
- There is negligible risk to human and ecological health from the consumption of aquatic biota and environmental values relating to aquatic food consumption and aquaculture
- Surface water quality is considered currently suitable for recreational use
- Groundwater from potable abstraction bores is considered currently suitable for drinking water purposes and recreational use
- Groundwater from abstraction bores is considered currently suitable for industrial purposes
- There is a negligible impact on cultural and spiritual values of the water.

Suggested Future Management Approach

The suggested future management approach is for ongoing biannual monitoring of groundwater, surface water and sediment to allow the latest PFAS concentrations to be assessed, to inform changes in trends and to inform current risk to potential receptors.

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13.0 Limitations

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