

Department of Defence

RAAF Base Darwin

Detailed Site Investigation -
Per- and Poly-fluoroalkyl Substances (PFAS)
Executive Summary

7 February 2018



Results emerge
when local knowledge
intersects with
global expertise

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RAAF Base Darwin

Prepared for
Department of Defence

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EXECUTIVE SUMMARY

Introduction

Department of Defence has engaged Coffey Environments Australia Pty Ltd (Coffey) to undertake a Detailed Site Investigation of per- and poly-fluoroalkyl substance (PFAS) site conditions at RAAF Base Darwin (the Site). The extent of the area of the Detailed Site Investigation incorporates the base, and surrounding off-base areas to the extent necessary (based on current understanding) to characterise the nature and extent of PFAS contamination derived from RAAF Base Darwin activities.

RAAF Base Darwin is an operational joint civil-military airfield. The base has administrative, accommodation, recreational and operational support facilities as well as technical workshops, aircraft hardstands and aircraft pavements. The airfield supports Australian and international military aircraft operations. Air movement areas (runways and taxiways) are utilised by both civilian air operations and Defence. Darwin International Airport is classified as a Jointly Used Airport under the *Airports Act 1996* (Cth).

This document is a summary of the assessment and findings that are detailed in the Detailed Site Investigation Report (reference 754-MELEN199421_R05, dated 5 February 2018).

PFAS background

Per- and poly-fluoroalkyl substances (PFAS) are a group of manufactured chemicals that have been used since the 1950s in products that are resistant to heat, water and oil. Due to their heat resistant properties, and ability to form aqueous film forming foams (AFFF), they have been used extensively in fire-fighting foam applications in Australia for decades. A significant amount of research has been conducted into the health and ecological effects of these substances, and they are understood to be highly persistent within the environment, readily leachable from soils, and bio-accumulate up the food-chain. The potential health and ecological effects of these substances are not well defined, however given their environmental persistence, enHealth has issued a precautionary warning to limit exposure to humans from these compounds.

Defence historically used AFFF containing per-fluorooctane sulfonate (PFOS) on the greater Defence estate between approximately 1983 and 2009. Defence recognised that the former use of these chemicals may have resulted in releases to the environment. They are seeking to better understand the nature and extent of PFAS impacts on the Site via a comprehensive investigation of PFAS site conditions to meet the aims of Defence's National Plan for managing PFAS contamination on the greater Defence Estate.

AFFF containing PFAS were routinely used for fire training activities, hangar and fuel farm fire suppression system operation and testing, incident response and response equipment testing. The volume and extent of AFFF discharged at each of the source areas is likely to have varied considerably, and it is recognised that several of the identified source areas present a higher likelihood of PFAS impact (such as where AFFF was used frequently including fire training areas and hangars).

The fully fluorinated compounds (per) do not readily degrade and will remain in the environment for many decades. Poly-fluorinated compounds may degrade in the environment (under certain conditions) to per-fluorinated compounds. The compounds are water soluble and mobile, and will tend to migrate with water. Different compounds in the group adsorb at different rates to organic carbon in soil. Long chain compounds (six or more carbons) also bioaccumulate in animals. Due to the high mobility, PFAS compounds can be present in very large plumes associated with groundwater migration and surface waters. Organic rich sediments may act as ongoing or seasonal sources of PFAS contamination to surface waters through leaching.

Objective and scope

The environmental investigation of potential PFAS contamination is focussed on characterising sources of contamination as a result of the use, storage and waste management of historical potential AFFF products on the Base. In accordance with the principles of the National Environment Protection (Assessment of Site Contamination) Measure, a conceptual site model is developed to identify

possible connections between potential contamination and humans, the human food chain or ecology. Sampling of soils, waters and biota is then conducted to validate the model, and quantify the exposure pathways between the sources and receptors. These outcomes then guide the development and implementation of appropriate risk management actions associated with identified PFAS risks.

The objective of the Detailed Site Investigation was to:

- Identify known and potential sources of PFAS contamination;
- Characterise the site setting sufficient to describe likely contaminant migration behaviour;
- Identify receptors and the associated exposure concentrations;
- Delineate and characterise PFAS contamination in source areas on the Base to inform preliminary risk assessment and contaminant transport models.

An Investigation Area was defined to reflect the extent of potential PFAS impact to focus the investigation, based on suspected release sites and contaminant migration pathways. The Investigation Area is shown in Figure A.



Figure A – Base Location and Investigation Area

The Detailed Site Investigation scope that is described in this report involves:

- Literature review: Review of over 50 historic reports and documents
- Soil: Collection and analysis of approximately 430 soil samples and 180 sediment samples for PFAS
- Surface Water: 85 samples across four events, including 12 locations in Rapid Creek, four in Ludmilla Creek, and six locations in drains that feed into Ludmilla Creek, six in Reichardt Creek, and four in Sadgroves Creek
- Groundwater: Installation of 104 targeted groundwater monitoring wells. Collection of 258 groundwater samples from 153 locations during two main monitoring events in April and September 2017. Vertical profiling in 18 wells and aquifer hydraulic conductivity testing in 17 wells

- Aquatic biota: 12 whole body fish and crayfish samples from four locations in Rapid Creek, and four whole body fish samples from one location in Ludmilla Creek. Aquatic biota studies were also conducted by Charles Darwin University and University of Queensland on behalf of NT Department of Health and involved testing of finfish, crustaceans and molluscs from Rapid Creek and Ludmilla Creek

Additional monitoring of contaminant concentrations in surface water and groundwater will continue across November 2017 to March 2018 to monitor seasonal fluctuations and inform development and refinement of contaminant transport models. These models will provide input to the sensitivity review of risk assessments to guide appropriate risk management approaches. Further biota assessment will also occur to inform the assessment of risk to human health and ecosystems as a result of bioaccumulation of PFAS compounds in the environment.

Sources

PFAS source areas that were identified in the site history and literature review and subsequently confirmed to contain elevated concentrations of PFAS are described in the table below.

Other areas, as shown on Figure B, were identified for investigation through the site history review, however subsequent investigation did not confirm the areas as current or former sources of PFAS contamination.

Area	Extent of Impact	Media	Concentration Ranges
Hangar 31 (NT1031) and Former Fuel Farm 1 (NT0201)	<p>Several AFFF release events from the hangar resulted in PFOS contamination of soils and drains surrounding the hangar. Remediation of surface soils removed soils with the highest concentrations, however concentrations of up to 9 mg/kg remain. Maximum concentrations are inferred to be present at approximately 0.5 to 1.0 m. An AFFF fire suppression system was present in the former Fuel Farm 1 facility, which is also inferred to have had releases, based on elevated concentrations reported in soil in historic assessments.</p> <p>Concentrations in groundwater immediately south of the hangar and down gradient indicate infiltration to groundwater occurred in the vicinity of the hangar, which has migrated west southwest beyond the western boundary of the base.</p> <p>Historic results of sampling in stormwater drains leading from the hangar to Ludmilla Creek have also indicated high concentration of PFOS, indicating that this was a migration pathway at the time of the AFFF releases. Recent sampling has indicated detectable concentrations in stormwater in the drain that connects the Site to Ludmilla Creek, however this result may potentially reflect groundwater seepage into the drain.</p>	Soil	Up to 9 mg/kg PFOS. Lower concentrations in top 0.1m.
		Surface water	To be assessed
		Groundwater	Maximum reported in 2017, 15 µg/L PFOS+PFHxS
Former ARFF Fire Station	<p>A former Airport Rescue and Fire Fighting (ARFF) Fire Station, operated by Airservices post-1995, and previously by Civil Aviation Authority and the Commonwealth Department of Civil Aviation, was located on the south side of the runway, near the current Ordnance Loading Aprons (OLAs). The station was built in 1958 (Brown & Root 2000) and operated until approximately 1999.</p> <p>The former ARFF fire station had not been investigated prior to 2017. The extent of recent investigations have been limited by the presence of OLAs and taxiways, however the assessment has confirmed elevated concentrations of PFOS and PFHxS in soil and groundwater in the area of the former fire station.</p> <p>Soil impact concentrations appear to be highest at approximately 0.5 to 1 m bgs and highly leachable.</p> <p>Groundwater impact from the former ARFF fire station appears to be migrating to the south southwest, and potentially to the north northwest, as the location is on a groundwater divide. Concentrations above the groundwater screening values are migrating across the southern boundary.</p>	Soil	Maximum reported 0.32 mg/kg PFOS 7.7 µg/L PFOS leachate (ASLP)
		Surface water	To be assessed
		Groundwater	Maximum reported 820 µg/L PFOS+PFHxS

Area	Extent of Impact	Media	Concentration Ranges
Former RAAF Fire Station (Bld 558)	<p>The former RAAF fire station operated until 1992 and had not been investigated prior to 2017. Moderate levels of PFOS were identified in soils across the area investigated with maximum concentrations reported at the north eastern corner at 1 m depth. Concentrations in the top 0.5 m were below human health based screening values.</p> <p>Maximum concentrations in groundwater were reported in the north eastern corner of the area and impact has been observed to migrate to the south west and cross the southern and western boundaries.</p>	Soil	<p>Maximum 3 mg/kg PFOS, but typically below 0.3 mg/kg.</p> <p>Maximum leachate reported 29 µg/L PFOS (ASLP).</p>
		Surface water	To be assessed
		Groundwater	Maximum 17.3 µg/L PFOS+PFHxS
Former Fire Training Ground 1 (NT0241)	<p>The training ground was regularly used by RAAF fire section and ARFF for AFFF training and testing activities until the late 1990s. The surface was scraped and stockpiled when the area was decommissioned as a training ground. The maximum concentrations reported in the area were in the stockpiled soil and immediately surrounding it. Concentrations of PFOS above the human health based screening value for a recreational setting were reported in an area approximately 50 x 80 m. Concentrations above terrestrial ecological screening levels were only exceeded in an isolated location.</p> <p>Sediment concentrations in drains to the north of the area have historically been high, with detectable concentrations in sediment leading to Rapid Creek.</p> <p>Maximum concentrations in groundwater have been reported on the northern edge of the former training area, with impact migrating to the north towards Rapid Creek and to the south across the southern boundary.</p>	Soil	<p>Maximum 70 mg/kg PFOS</p> <p>Maximum leachate 189 µg/L PFOS</p>
		Surface water	To be assessed
		Groundwater	Maximum in 2017, 37 µg/L PFOS+PFHxS
Former Fire Training Ground 2 (NT1030 / NT0242)	<p>The training ground was regularly used by RAAF fire section and ARFF for AFFF training and testing activities until late 1990s. The site is now within the Darwin International Airport (DIA) lease. Elevated concentrations have been reported in soil in an area of at least 100 x 100 m. Maximum concentrations were reported at the surface, and the nominated human health based screening value for recreational use was exceeded across an area of approximately 50 x 50m. No results exceeded terrestrial ecosystem screening values.</p> <p>Concentrations in groundwater in the source area and downgradient (north) exceeded screening criteria for recreational use and represent a potential source of impact to Rapid creek (1 km north) at concentrations that would exceed aquatic ecosystem protection values.</p>	Soil	Maximum 30 mg/kg PFOS
		Surface water	To be assessed
		Groundwater	Maximum in 2017, 6.3 µg/L PFOS+PFHxS (MW197)

Area	Extent of Impact	Media	Concentration Ranges
Current Fire Training Ground (NT0243)	<p>The training ground is operated by Airservices, and was used for AFFF training and testing (predominantly 3M Lightwater to 2003 and then Ansulite to 2010) but is also used by RAAF and visiting groups occasionally. Elevated concentrations of PFAS compounds have been reported across an area of approximately 300 x 200m around the current fire training ground and along the drainage line to the north. Maximum concentrations have been reported east of the pad. Isolated samples have contained concentration in excess of human health screening values for a recreational type exposure setting. Concentration in sediments in infrastructure were high and exceeded terrestrial ecological screening values.</p> <p>Waste water samples from the collection system and effluent tanks have reported high residual concentrations of PFOS and other PFAS compounds.</p> <p>Groundwater beneath the training area has elevated concentrations of PFAS concentrations above human health screening levels for extractive uses and with the potential to be a source of impact to receiving waters of Rapid Creek.</p>	Soil	Maximum 10.6 mg/kg PFOS
		Surface water	To be assessed
		Groundwater	Maximum in 2017, 59 µg/L PFOS+PFHxS (243_MW02)
		Effluent	Maximum 210 µg/L PFOS and 95 ug/L PFOA
Former Fuel Farm 4 (NT0205) Former Fuel Farm 5 (NT0206) Former Fuel Farm 6 (NT0207)	<p>Fuel Farms 4, 5 and 6 comprised foam fire suppression systems when operational. Elevated concentrations of PFAS in soil have been reported at each of the former fuel farms. Concentrations are typically highest at a depth of 0.5 to 1m and has been reported at high concentrations to 4m. Although not fully delineated, the impact covers an area of approximately 50 x 50 m for former Fuel Farms 5 and 6, and an area of at least 100 x 100m at Fuel Farm 4.</p> <p>Concentrations in groundwater are elevated beneath each of the former fuel farms at concentrations that potentially pose a source of impact to receiving water bodies (Rapid Creek to the north and Reichardt Creek to the south).</p>	Soil	Maximum 12 mg/kg PFOS (at 0.5 m in Fuel farm 4)
		Surface water	No data
		Groundwater	Maximum 108 µg/L PFOS+PFHxS (at Fuel farm 6)
Stockpiled AFFF Contaminated Soil (NT1002 / NT0247)	<p>Contaminated soils generated during remediation of Hangar 31 AFFF release incidents are stored securely on-base. Concentrations of PFAS compounds in the stockpiled soils are elevated, with concentrations of PFOS up to 55 mg/kg. However the soils are contained and do not represent a current source of impact to human health or the environment. Soil sampling in the vicinity of the stockpiles has indicated localised PFOS concentrations exceeding human health screening criteria, which may represent spills during stockpile relocation, or may relate to migration from contaminant sources at the former fuel farms to the north.</p> <p>Groundwater impact in the vicinity of the stockpiles is considered to be related to migration from source areas to the north.</p>	Soil	Maximum 1.3 mg/kg PFOS
		Surface water	No data

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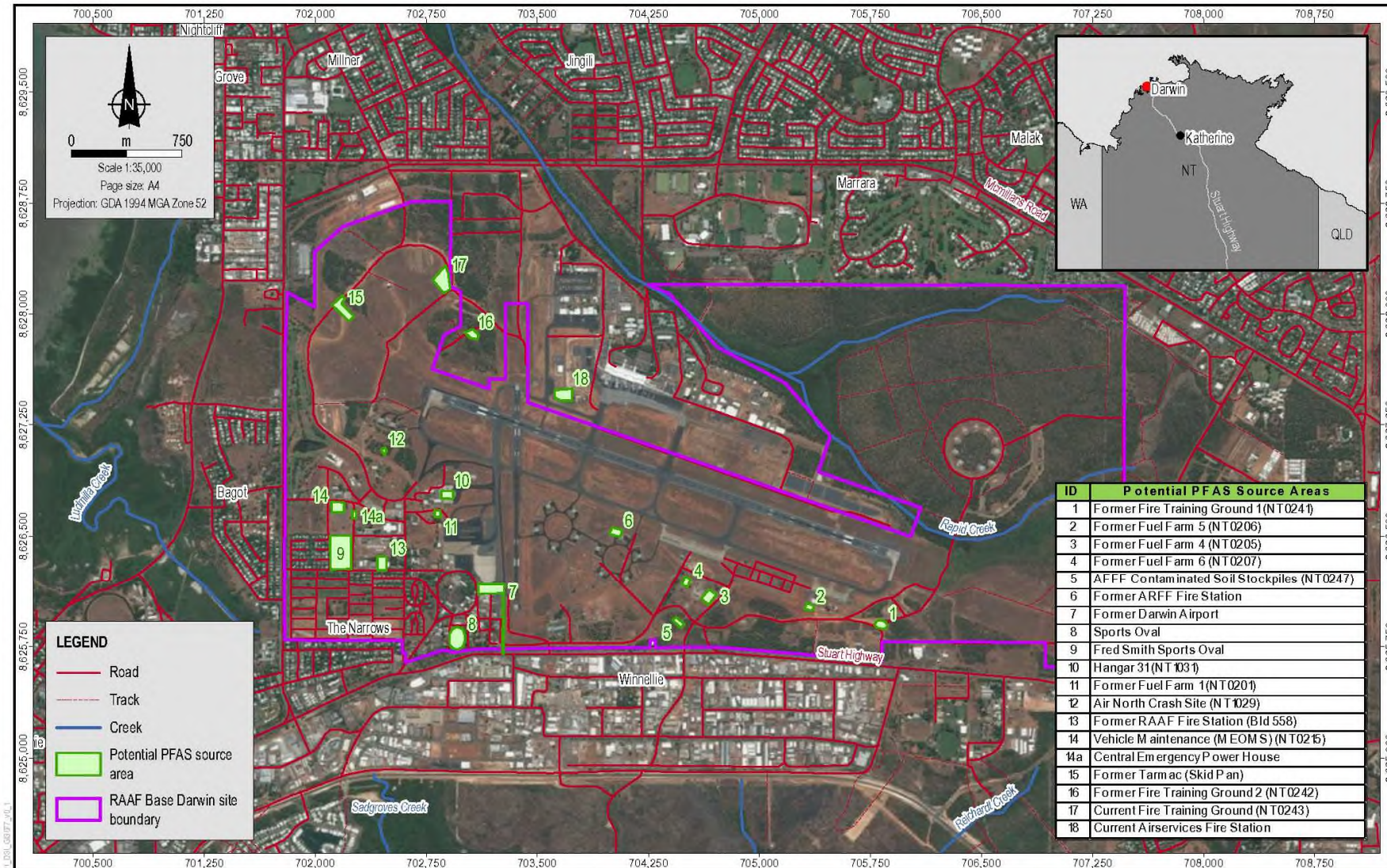


Figure B – Locations of Identified Potential PFAS Source Areas

Pathways

Potential pathways for the migration of PFAS from the source areas to locations where human or environmental exposure may occur include the following:

- Vertical migration of PFAS through soil to groundwater;
- Leaching of PFAS from impacted soils into groundwater or surface water;
- Surface water runoff of PFAS to Site drains, depressions, open pits and surrounding creeks;
- Migration of PFAS in surface water (Site drains and surrounding creeks) to down-stream areas;
- Infiltration of PFAS in surface water to soil and groundwater;
- Lateral migration of PFAS in groundwater with the flow of the aquifer;
- Abstraction of groundwater for domestic, irrigation and stock watering use;
- Discharge of groundwater into surface waters and associated sediments; and
- Uptake of PFAS in sediment, groundwater and surface water by biota.

Off-base surface water impact

The Investigation Area (IA) sits across four broad watersheds with surface water discharging to:

- Ludmilla Creek to the west, and eventually Fannie Bay,
- Rapid Creek to the north and eventually Beagle Bay,
- Reichardt Creek to the east and south, and Sadgroves Creek to the south (which both discharge to Darwin Harbour).

The groundwater conditions across the IA also reflect the topography with groundwater flowing to the north, west and south from a central location on the base (the OLA and former ARFF Fire Station). Seasonal effects result in groundwater levels falling by up to 4 m from the end of the wet season to the end of the dry season, which in-turn affects contaminant migration by changing hydraulic gradients and changing the geological units that groundwater is in contact with.

A description of each off-base water body is provided below, with a summary of the available analytical data. Screening values are also provided for comparison in the left column.

Rapid Creek		
Catchment	The Rapid Creek catchment encompasses the eastern and northern portion of the base, and is the predominant water catchment extending across approximately 70% of the base. Rapid Creek is the closest surface water body to the base, it is approximately 9.8 km in length, drains a catchment of approximately 30km ² , and flows in a general northwesterly direction.	
Associated source areas	Former Fire Training Ground 1, Former Fuel Farms 4, 5 and 6, Former ARFF Fire Station, Former Fire Training Ground 2, Current Fire Training Ground	
Media	Extent of Impact	Concentration Ranges
Surface water	<p>Recreational SV 0.7 µg/L PFOS+PFHxS</p> <p>Ecosystem SV 0.00023 µg/L PFOS</p>	<p>Marrara Swamp (up-stream of base impact) <0.01 µg/L PFOS</p> <p>Freshwater reach, adjacent to DIA and base 0.35 to 2.2 µg/L PFOS</p> <p>Tidal reaches <0.01 to 0.26 µg/L PFOS</p>
Sediments	<p>Human health SV 600 µg/kg PFOS</p> <p>Indicative ecological SV 10 µg/kg PFOS</p>	<p>Freshwater reach, adjacent to DIA and base <5 µg/kg to 390 µg/kg PFOS</p>
Animal biota	Studies of molluscs, and finfish (CDU 2017b, UQ 2017 and Coffey) has identified detectable impact in specimen caught adjacent to and downstream of the base.	<p>Maximum mudcrab muscle 12 µg/kg PFOS</p> <p>Maximum fish (whole) 1,200 µg/kg PFOS</p> <p>Maximum crayfish 78 µg/kg PFOS</p>
	<p>Crustaceans 65 µg/kg PFOS</p> <p>Finfish (fillets) 5.2 µg/kg PFOS</p>	

Ludmilla Creek		
Catchment	The Ludmilla Creek catchment incorporates the western portion of the base, from the northwest in the area of the skid pan, the area beyond the western end of the 18/36 runway, and in the south west portion of the base, the area around Hangar 31 (NT1031) and the former RAAF Fire Station. Drainage occurs mainly as sheet flow that collects in small, unlined drains before discharging into several drainage systems under Bagot Road.	
Associated source areas	Former RAAF Fire Station, Hangar 31, Former ARFF Fire station	
Media	Extent of Impact	Concentration Ranges
Surface water Recreational SV 0.7 µg/L PFOS+PFHxS Ecosystem SV 0.00023 µg/L PFOS	PFAS has been detected in surface waters in Ludmilla Creek and drains leading to the creek. The maximum concentrations reported are in stormwater drains discharging from the base.	<0.01 to 0.22 µg/L PFOS Drains leading to Ludmilla Creek 0.05 to 4.4 µg/L PFOS
Sediments Human health SV 600 µg/kg PFOS Indicative ecological SV 10 µg/kg PFOS	Samples collected by Coffey in 2017 did not contain concentrations above the nominated detection limits.	<5 µg/kg PFOS
Animal biota Crustaceans 65 µg/kg PFOS Finfish (fillets) 5.2 µg/kg PFOS	Assessments conducted by Coffey, CDU and UQ have identified detectable concentrations of PFAS compounds in fish and crustaceans from Ludmilla Creek.	Max. mudcrab 3 µg/kg PFOS Max fish (whole) 120 µg/kg PFOS Max Prawn 46 µg/kg PFOS

Sadgroves Creek and Reichardt Creek		
Catchment	The Sadgroves Creek and Reichardt Creek catchment encompass a smaller southern portion of the base. This includes an area to the south of the OLAs (NT0242), and incorporates at least part of the area where the former Darwin Airport operated, and a sports field near the entrance to the base.	
Associated source areas	Former Fire Training Ground 1, Former Fuel Farms 4, 5 and 6, Former ARFF Fire Station	
Media	Extent of Impact	Concentration Ranges
Surface water Recreational SV 0.7 µg/L PFOS+PFHxS Ecosystem SV 0.00023 µg/L PFOS	Detectable concentrations of PFAS have been reported in 2017 in the surface waters, with maximum concentrations at the upper reaches, where stormwater drains discharge.	Sadgroves Creek- <0.01 to 0.06 µg/L PFOS Reichardt Creek- <0.01 to 0.29 µg/L PFOS
Sediments Human health SV 600 µg/kg PFOS Indicative ecological SV 10 µg/kg PFOS	Of the ten samples collected by Coffey in 2017 only one contained concentrations of any PFAS above the nominated laboratory reporting limit. Concentration did not exceed human health or ecological screening values.	Maximum 7.1 µg/kg PFOS
Animal biota	No data	

Extraction bores

Several registered bores have been identified adjacent to the base that are being, or have been, used for irrigation purposes. Where testing of these bores has been possible, the concentrations of PFAS were reported below the nominated laboratory reporting limit for bores to the south east and east. Two bores to the northwest, close to Rapid Creek contained detectable concentrations of PFOS, below the health based guidance value for drinking water. These results indicate that there is a low risk to known users of groundwater off-base.

Receptors

Based on the reported concentrations and anticipated migration pathway, the potentially relevant receptors of PFAS contamination are:

- Site personnel in contact with surface soils in impacted areas on-Base;
- Maintenance or construction workers in contact with soils within the top metre of the soil profile, stockpiled soil, sediments, where interactions with groundwater may occur e.g. dewatering, excavations) and in surface waters (i.e. drains) on-Base;
- Terrestrial flora and fauna in contact with surface soils, stockpile and sediments on-Base;
- Aquatic flora and fauna in contact with surface water on-Site;
- Recreational users in Rapid Creek;
- People consuming fish, crustacea or molluscs from Rapid Creek, Ludmilla Creek, Sadgroves Creek and Reichardt Creek;
- Terrestrial flora and fauna in contact with sediments in the Rapid Creek, Ludmilla Creek Sadgroves Creek and Reichardt Creek catchments;
- Aquatic flora and fauna in Rapid Creek, Ludmilla Creek, Sadgroves Creek and Reichardt Creek;
- Potential users of extracted groundwater in areas of impacted groundwater off-Base.

The following table highlights where there is a potentially complete pathway connection between an area of contamination and people or ecology who could potentially be impacted by the contamination. The table also shows where the relevant exposure concentration exceeds the nominated tier 1 screening levels, which indicates that further investigation of risk to human health or the environment is warranted (highlighted yellow).

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Source Media	Exposure Pathway	Human receptors								Ecological receptors			
		On-base			Off-base					On-base		Off-base	
		On-site residents	On-site workers and visitors	Construction and maintenance workers	Off-site residents	Off-site workers	Off-site construction & maintenance workers	Off-site recreational users of water bodies	Off-site consumers of aquatic species	Terrestrial	Aquatic	Terrestrial	Aquatic
Soil	Dermal contact	X	X	X	X	X	X	NA	NA	NA	NA	NA	NA
	Incidental ingestion	X	Y	Y	X	X	X	NA	NA	NA	NA	NA	NA
	Inhalation – dust	Y	Y	Y	Y	Y	X	NA	NA	NA	NA	NA	NA
	Direct contact/ Uptake	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	NT	NA
	Bioaccumulation	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	NT	NA
Surface water	Dermal contact	X	X	X	X	X	X	X	NA	NA	NA	NA	NA
	Incidental Ingestion	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	NA	NA
	Direct contact/uptake	NA	NA	NA	NA	NA	NA	NA	NA	Y	Y	Y	Y
	Bioaccumulation	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	Y
Sediment	Dermal contact	X	X	X	NT	X	X	X	NA	NA	NA	NA	NA
	Incidental Ingestion	Y	Y	Y	NT	Y	Y	Y	Y	NA	NA	NA	NA
	Inhalation (dust)	Y	Y	Y	Y	Y	Y	Y	NA	NA	NA	NA	NA
	Direct contact/uptake	NA	NA	NA	NA	NA	NA	NA	NA	Y	Y	Y	Y
	Bioaccumulation	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	Y
Groundwater	Dermal contact	X	X	X	X	X	X	NA	NA	NA	NA	NA	NA
	Ingestion (direct or incidental)	X	X	Y	Y	Y	Y	NA	NA	NA	NA	NA	NA
	Direct contact/uptake	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	Y	NA
	Bioaccumulation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fish	Ingestion	NA	NA	NA	NA	NA	NA	NA	Y	NA	NA	NA	NA
Crustaceans	Ingestion	NA	NA	NA	NA	NA	NA	NA	Y	NA	NA	NA	NA
Molluscs	Ingestion	NA	NA	NA	NA	NA	NA	NA	Y	NA	NA	NA	NA

Table notes

X – Pathway not complete
Y – Pathway complete
NA – Not applicable
NT – Not tested

Below adopted screening criteria	Above adopted screening criteria	Screening criteria not available
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The human receptor pathways requiring further assessment relate to:

- ingestion of surface water during recreational activities
- incidental ingestion of surface water (or groundwater) during various activities (including maintenance and construction works, general Base use, and residential use On- and Off-Base)
- direct contact with impacted soils in source areas during construction and maintenance activities
- ingestion of fish or crustaceans from creeks within the vicinity of the Base.

Ecological receptors requiring further assessment include On-Base and Off-Base aquatic ecosystems within the surrounding creeks and typically where higher order receptors that feed on aquatic flora and fauna within surface water bodies, drains and flora are at risk of bioaccumulation impacts, as well as terrestrial ecosystems where soil and sediments are impacted.

The risks to human health or the environment are being assessed and documented in a Human Health Risk Assessment (HHRA), and an Ecological Risk Assessment (ERA), which will use the information described in this Detailed Site Investigation report and be supplemented by ongoing groundwater and surface water assessment to investigate seasonal trends. Biota testing will also be conducted to provide direct measurement and food web inputs to the HHRA and ERA.

This executive summary must be read in conjunction with the report proper and in the context of the limitations described in "Important information about your Coffey environmental report" attached.

Important information about your **Coffey** Environmental Report

Introduction

This report has been prepared by Coffey for you, as Coffey's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice,

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Coffey may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Coffey has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

Your report has been written for a specific purpose

Your report has been developed for a specific purpose as agreed by us and applies only to the site or area investigated. Unless otherwise stated in the report, this report cannot be applied to an adjacent site or area, nor can it be used when the nature of the specific purpose changes from that which we agreed.

For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination pose in the context of the agreed purpose. Such risks may be financial (for example, clean up costs or constraints on site use) and/or physical (for example, potential health risks to users of the site or the general public).

Limitations of the Report

The work was conducted, and the report has been prepared, in response to an agreed purpose and scope, within time and budgetary constraints, and in reliance on certain data and information made available to Coffey.

The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Coffey should be kept apprised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statutes and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

Interpretation of factual data

Environmental site assessments identify actual conditions only at those points where samples are taken and on the date collected. Data derived from indirect field measurements, and sometimes other reports on the site, are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions.

Variations in soil and groundwater conditions may occur between test or sample locations and actual conditions may differ from those inferred to exist. No environmental assessment program, no matter how comprehensive, can reveal all subsurface details and anomalies. Similarly, no professional, no matter how well qualified, can reveal what is hidden by earth, rock or changed through time.

The actual interface between different materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but

steps can be taken to reduce the impact of unexpected conditions.

For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of a suitably qualified and experienced environmental consultant through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other unrecognised features encountered on site. Coffey would be pleased to assist with any investigation or advice in such circumstances.

Recommendations in this report

This report assumes, in accordance with industry practice, that the site conditions recognised through discrete sampling are representative of actual conditions throughout the investigation area. Recommendations are based on the resulting interpretation.

Should further data be obtained that differs from the data on which the report recommendations are based (such as through excavation or other additional assessment), then the recommendations would need to be reviewed and may need to be revised.

Report for benefit of client

Unless otherwise agreed between us, the report has been prepared for your benefit and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendation and should make their own enquiries and obtain independent advice in relation to such matters.

Coffey assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report.

To avoid misuse of the information presented in your report, we recommend that Coffey be consulted before the report is provided to another party who may not be familiar with the background and the purpose of the report. In particular, an environmental disclosure report for a property vendor may not be suitable for satisfying the needs of that property's purchaser. This report should not be applied for any purpose other than that stated in the report.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, a suitably qualified and experienced environmental consultant should be retained to explain the implications of the report to other professionals referring to the report and then review plans and specifications produced to see how other professionals have incorporated the report findings.

Given Coffey prepared the report and has familiarity with the site, Coffey is well placed to provide such

assistance. If another party is engaged to interpret the recommendations of the report, there is a risk that the contents of the report may be misinterpreted and Coffey disowns any responsibility for such misinterpretation.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Responsibility

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.